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Fuller

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(54) **APPARATUS, SYSTEM AND METHOD FOR AERO-CONTOURING A SURFACE OF AN AERODYNAMICALLY FUNCTIONAL COATING**

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(51) **Int. Cl.**

B24B 23/03 (2006.01)
B24B 23/00 (2006.01)
B24B 55/10 (2006.01)

(52) **U.S. Cl.**

CPC ***B24B 23/03*** (2013.01); ***B24B 23/005*** (2013.01); ***B24B 55/102*** (2013.01)

(58) **Field of Classification Search**

CPC B24B 23/02; B24B 23/03; B24B 23/04; B24B 55/10; B24B 55/102; B24B 55/105; B24B 23/026

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See application file for complete search history.

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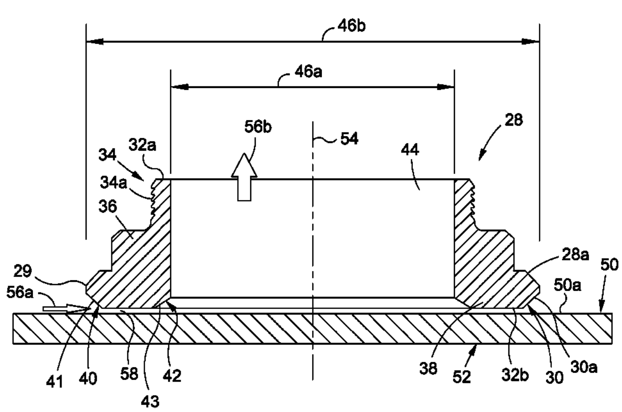
Primary Examiner — Monica Carter
Assistant Examiner — Marcel Dion

(57) **ABSTRACT**

An aero-contouring apparatus is provided. The aero-contouring apparatus has a housing assembly and a motor assembly disposed therein. The motor assembly has a motor unit and a drive unit. The aero-contouring apparatus further has an engagement force/tilt limiting member coupled to the housing assembly, which has a central opening and a bottom end configured to contact a surface to be aero-contoured of an aerodynamically functional coating applied to a structure. The aero-contouring apparatus further has an abrading unit coupled to the drive unit and inserted through the central opening in non-contact communication with the engagement force/tilt limiting member. The abrading unit is driven by the drive unit in a random orbit motion on the surface. The engagement force/tilt limiting member mechanically limits both an engagement force and any tilting motion of the abrading unit with respect to the surface.

20 Claims, 17 Drawing Sheets



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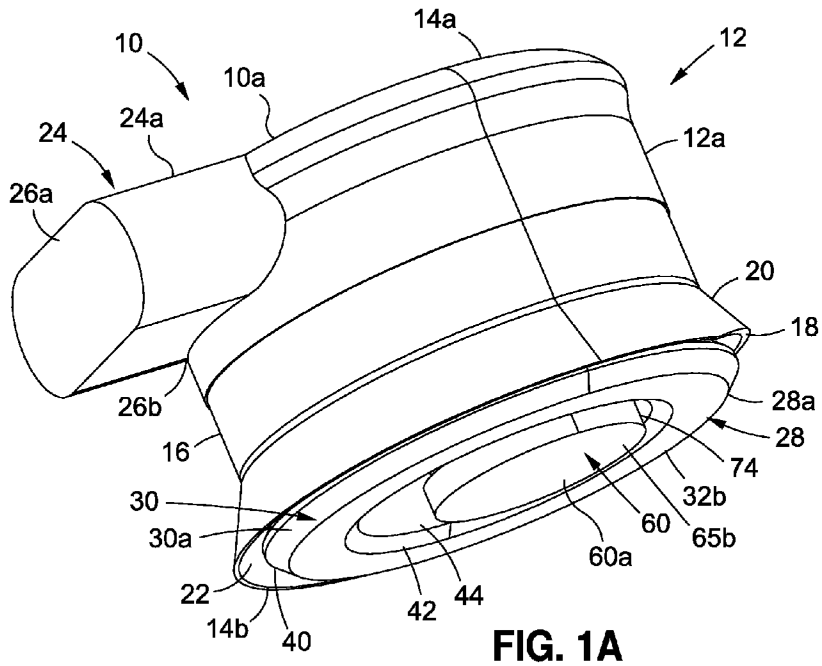
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60a
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14b
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40

FIG. 1A

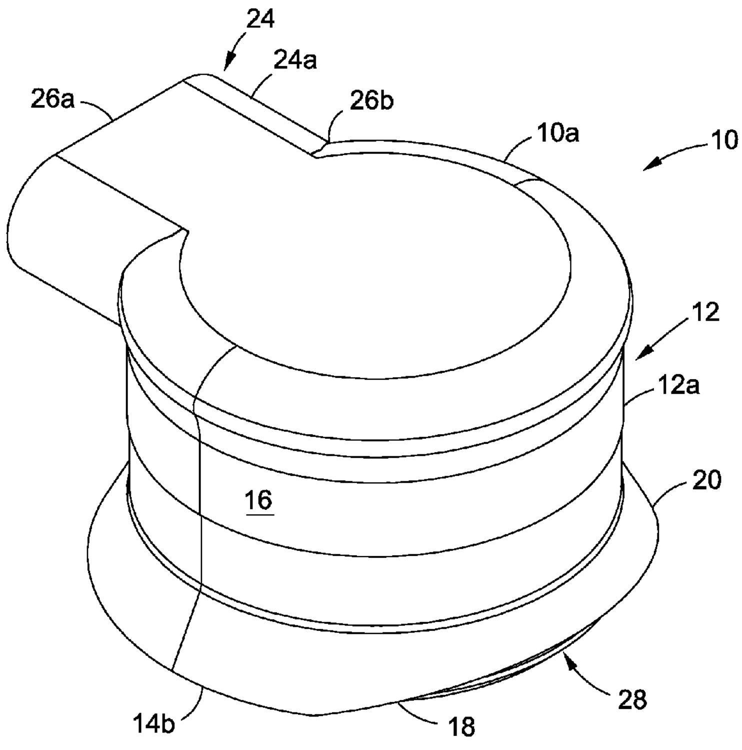
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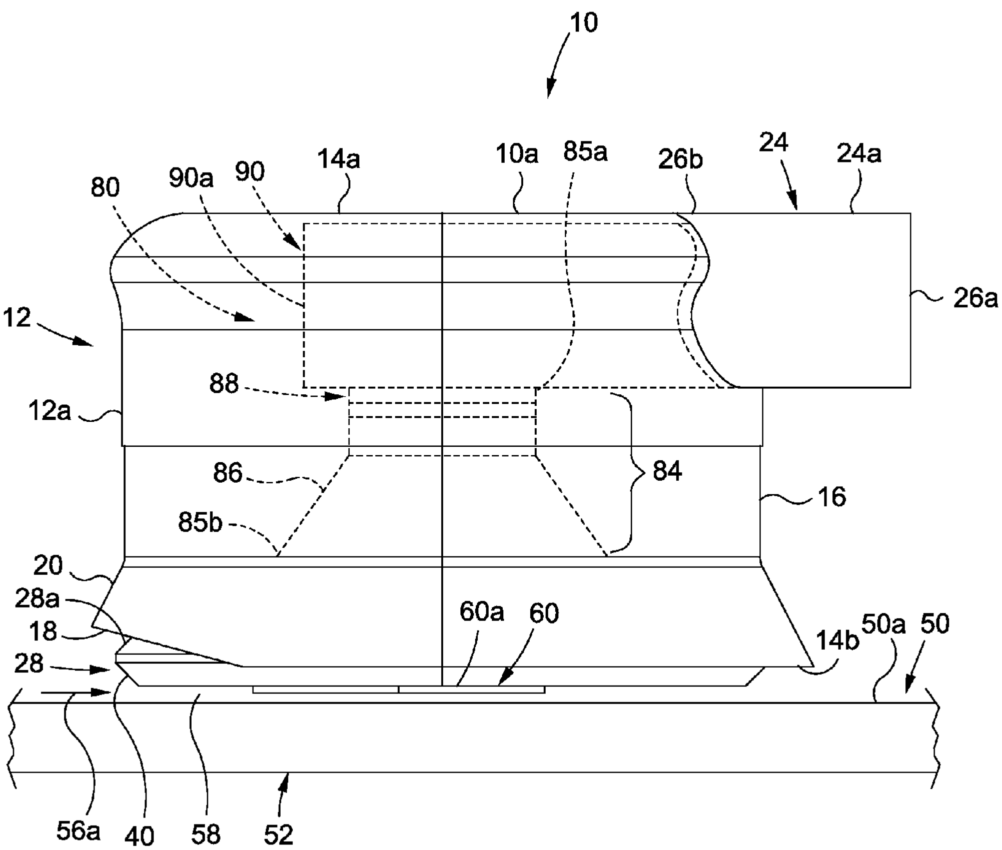
FIG. 1B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60a
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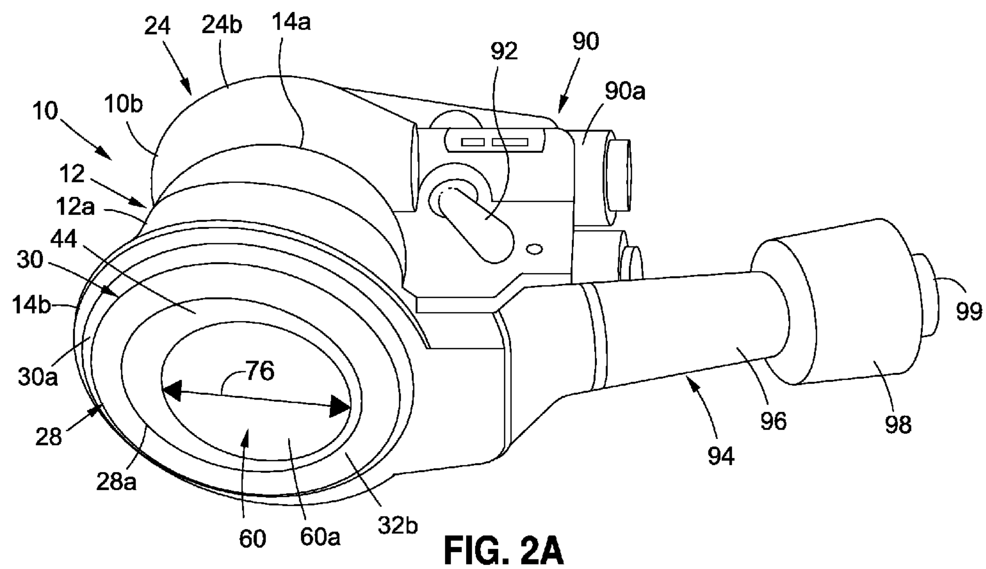
14b
50a
50
56a
40
58
52

FIG. 1C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32b
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96
98
99

FIG. 2A

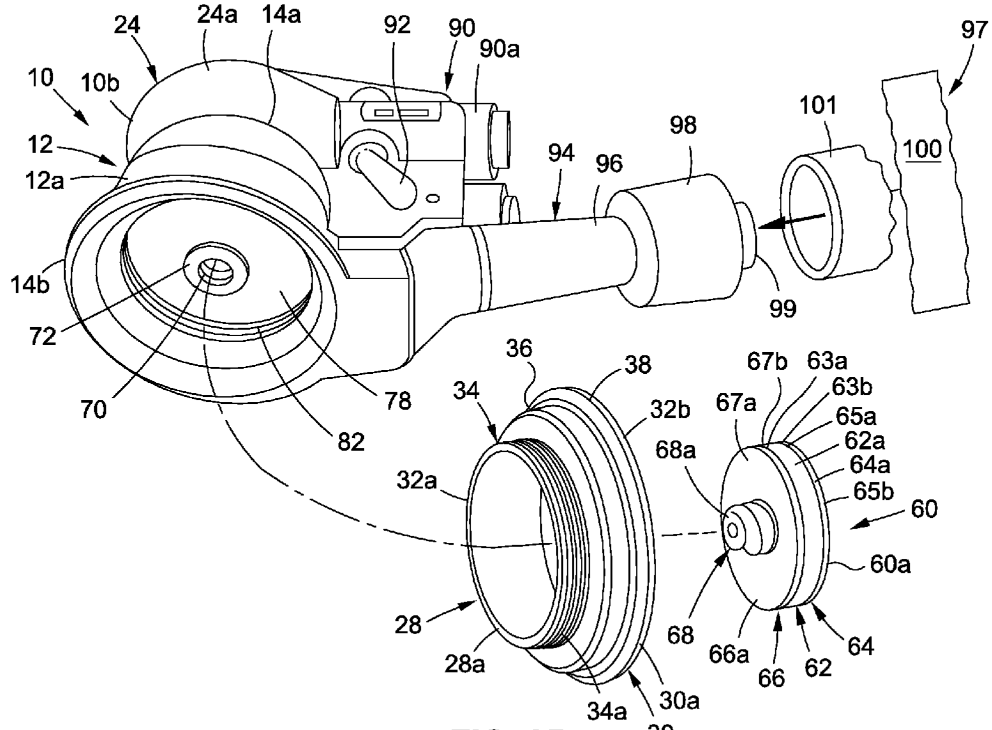
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FIG. 2B

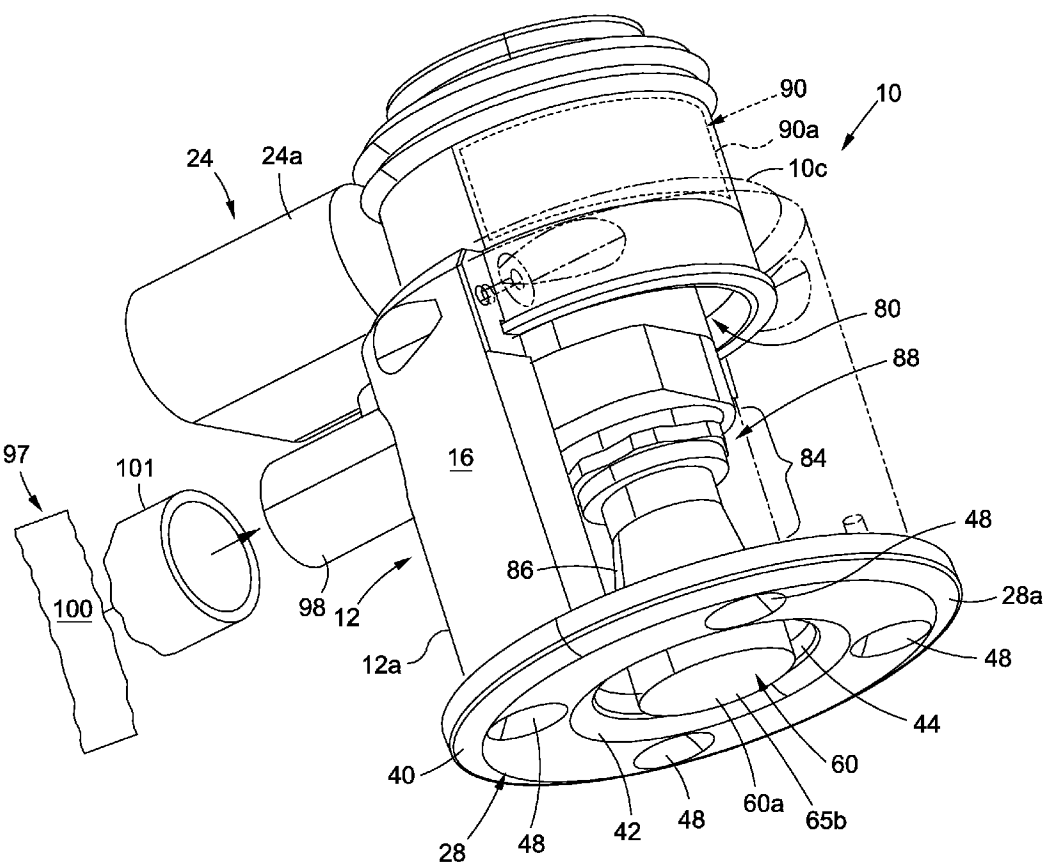
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FIG. 2C

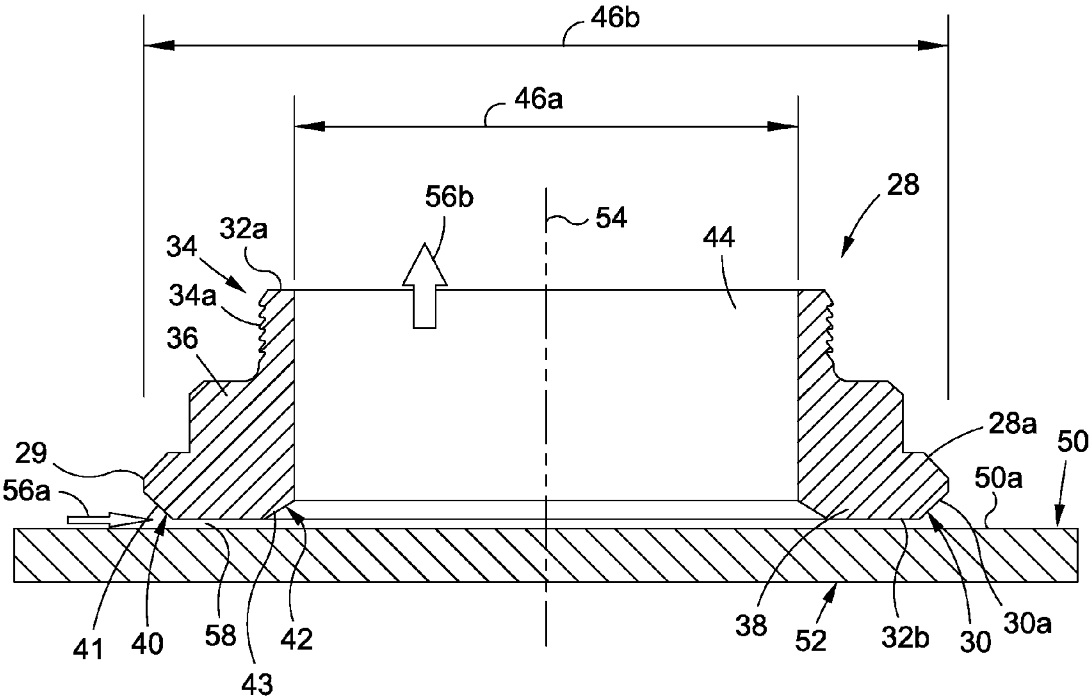
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FIG. 3A

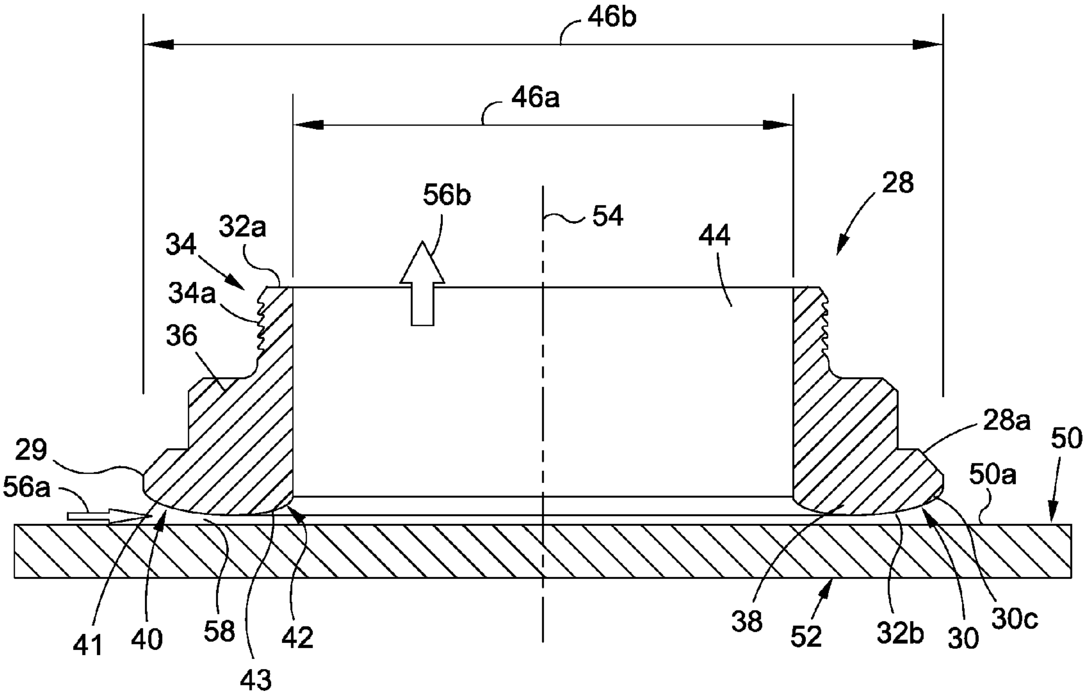
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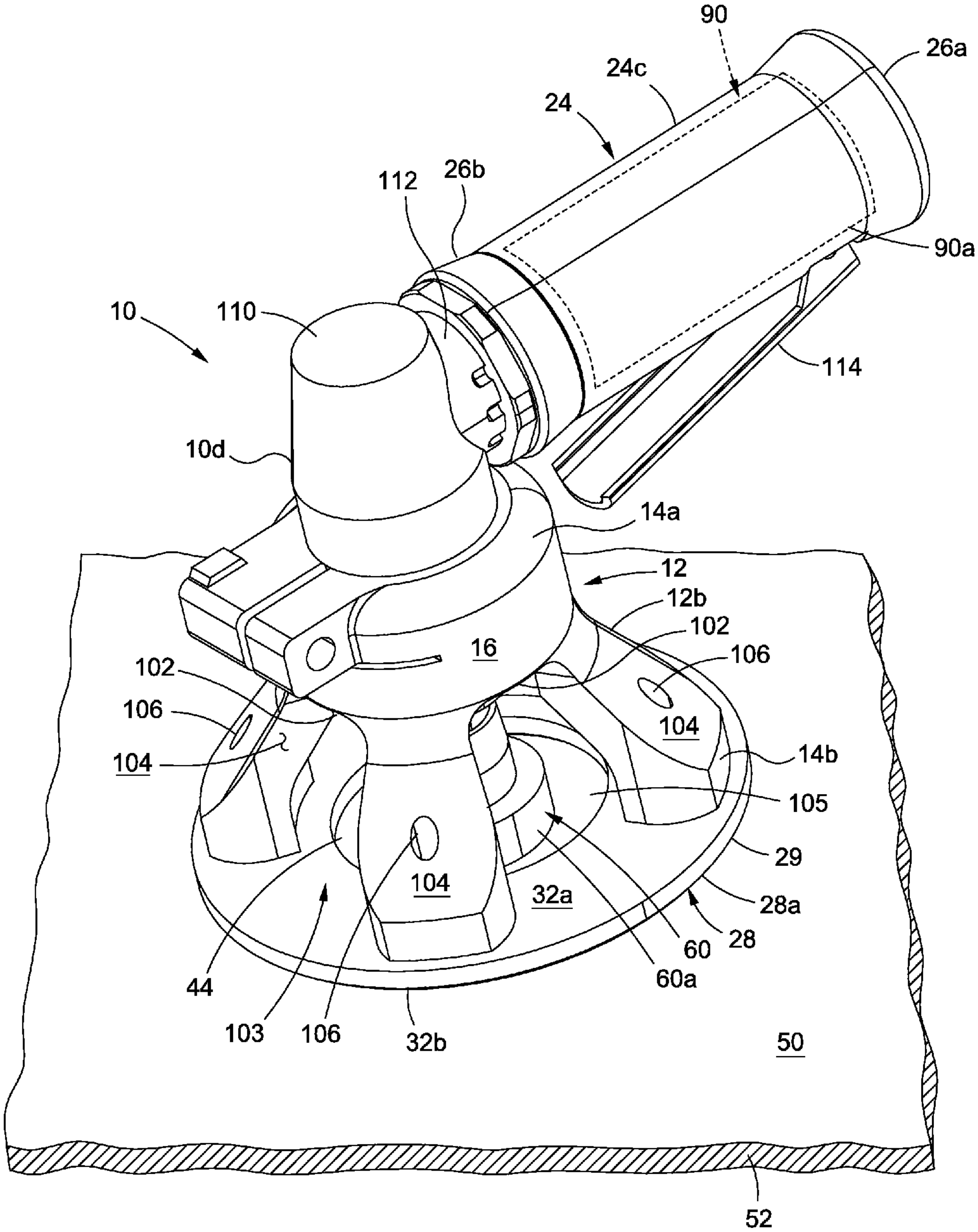
FIG. 3B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104
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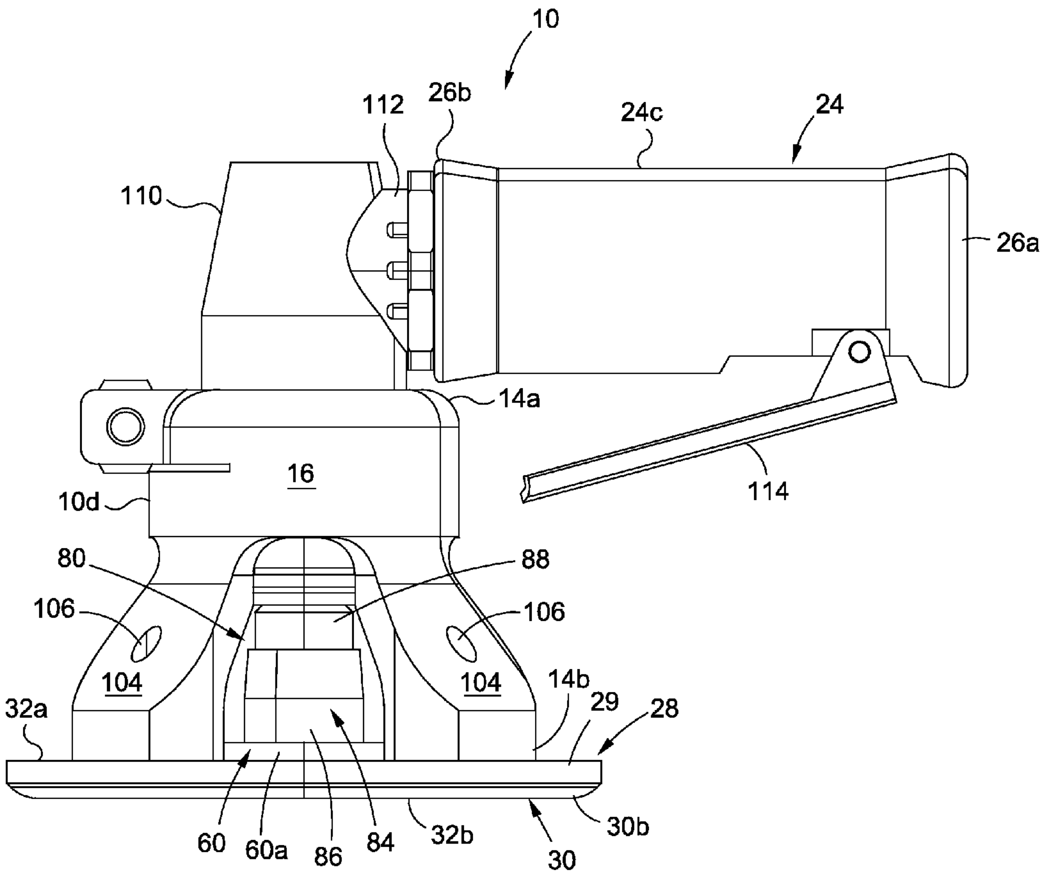
52

FIG. 4A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32b
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FIG. 4B

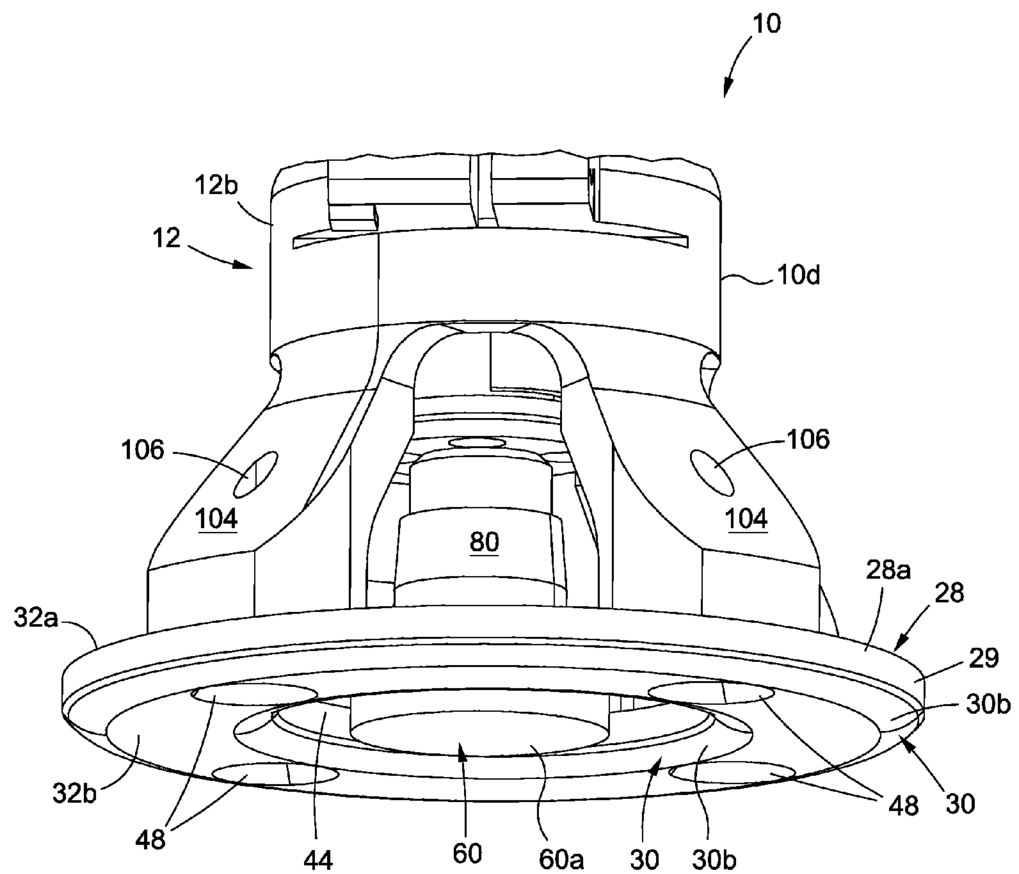
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FIG. 4C

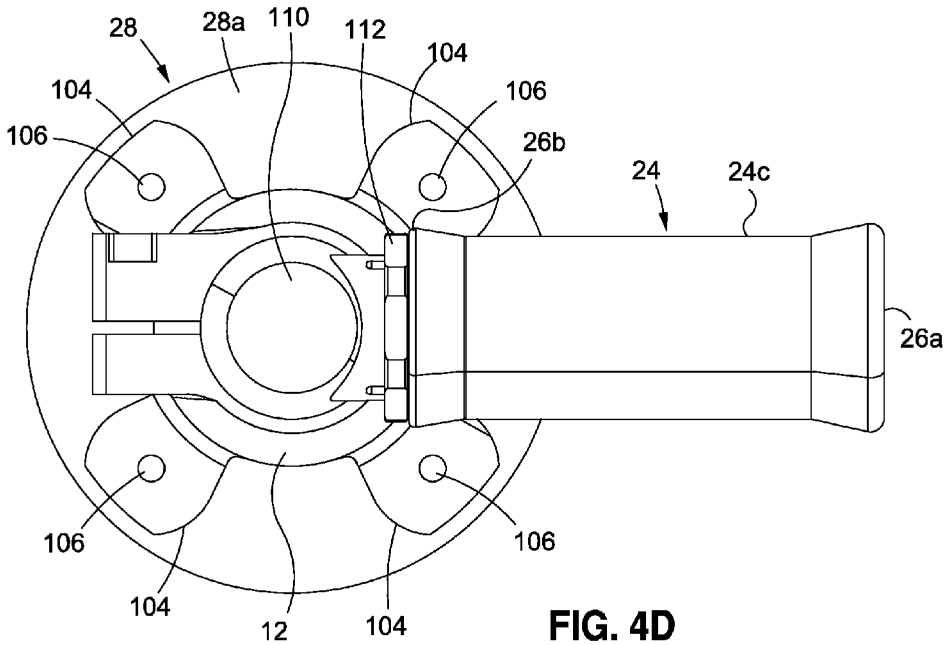
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FIG. 4D

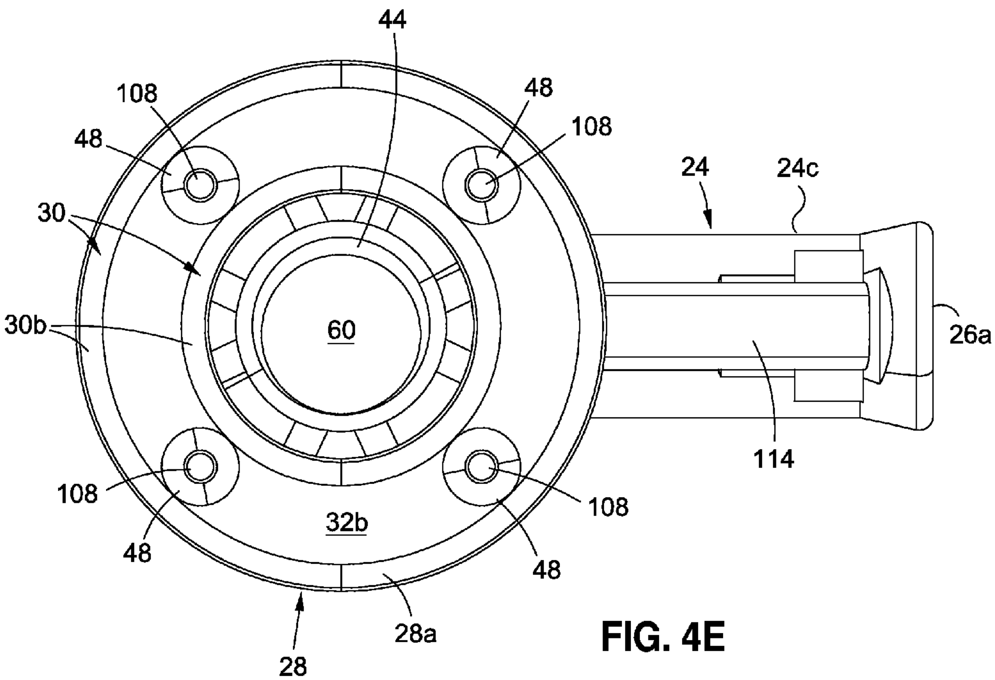
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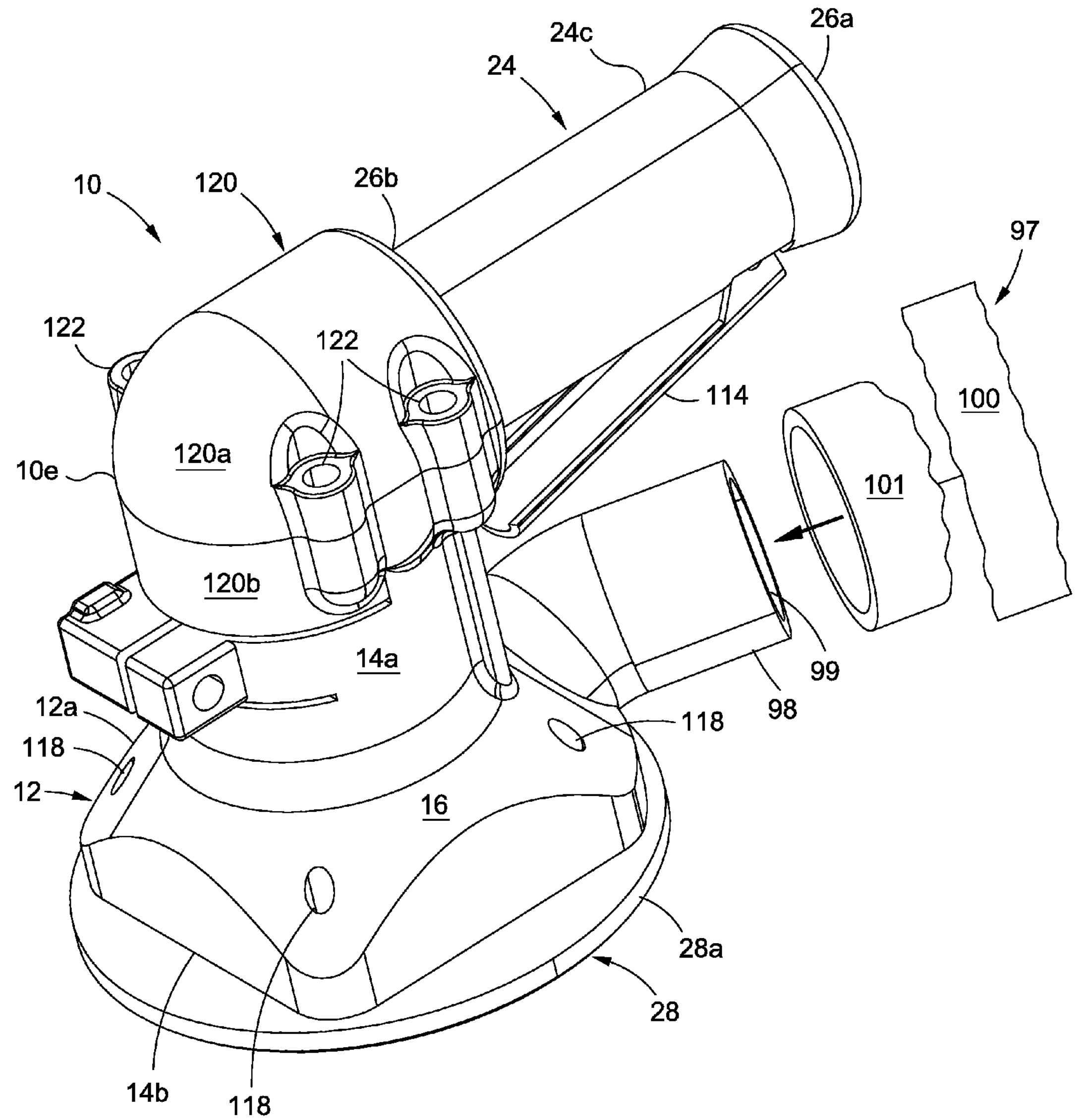
FIG. 4E



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14b
118

FIG. 5A

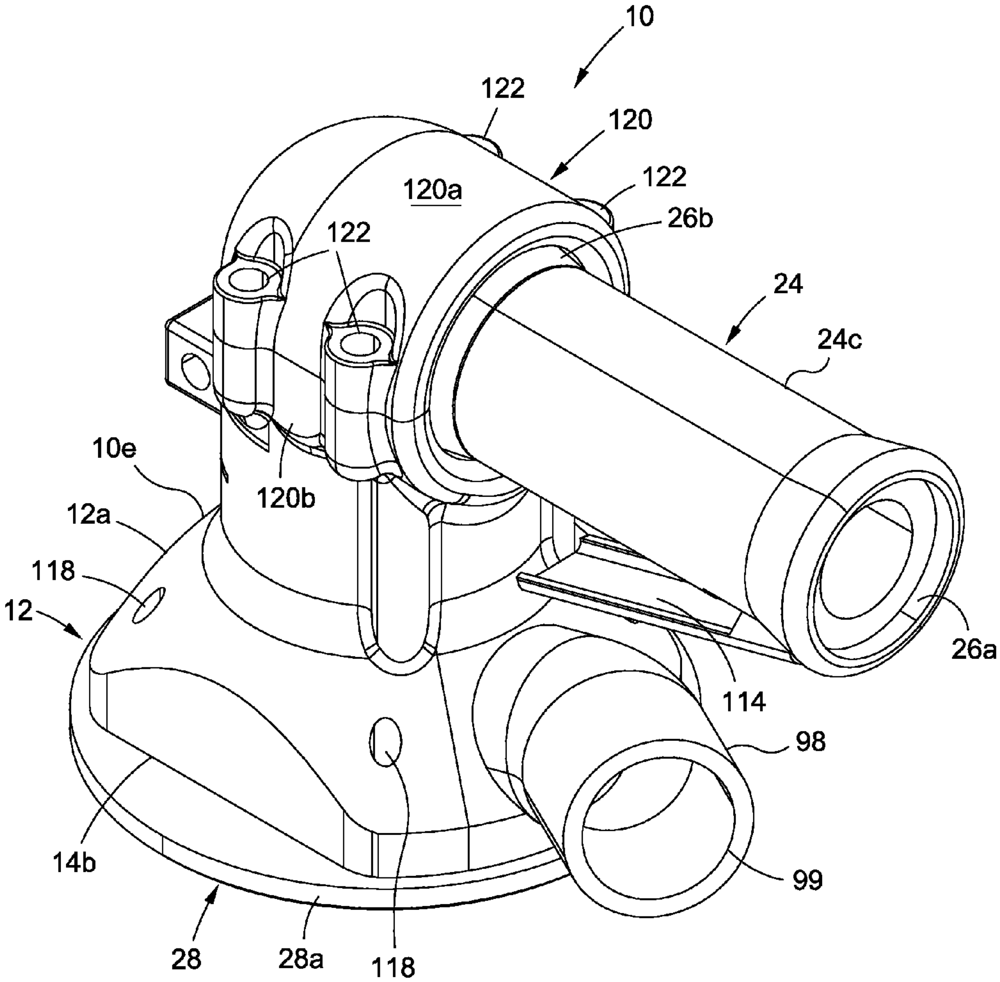
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FIG. 5B

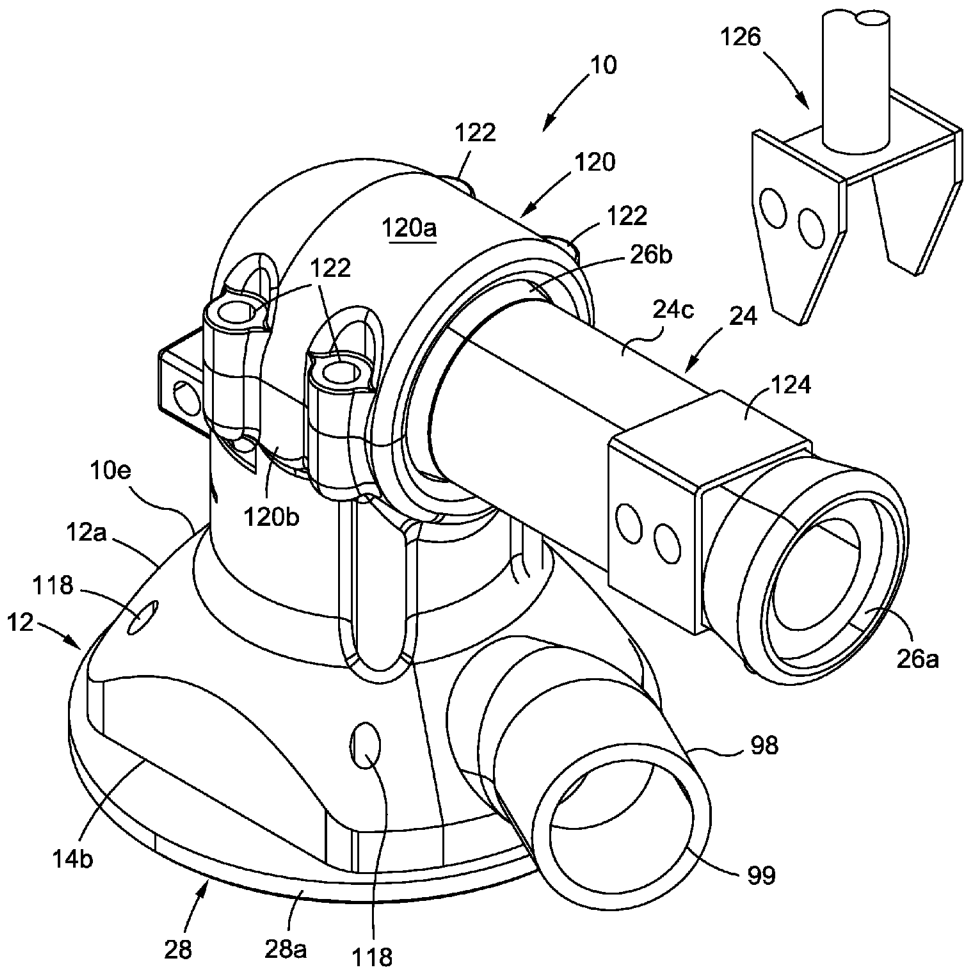
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FIG. 5C

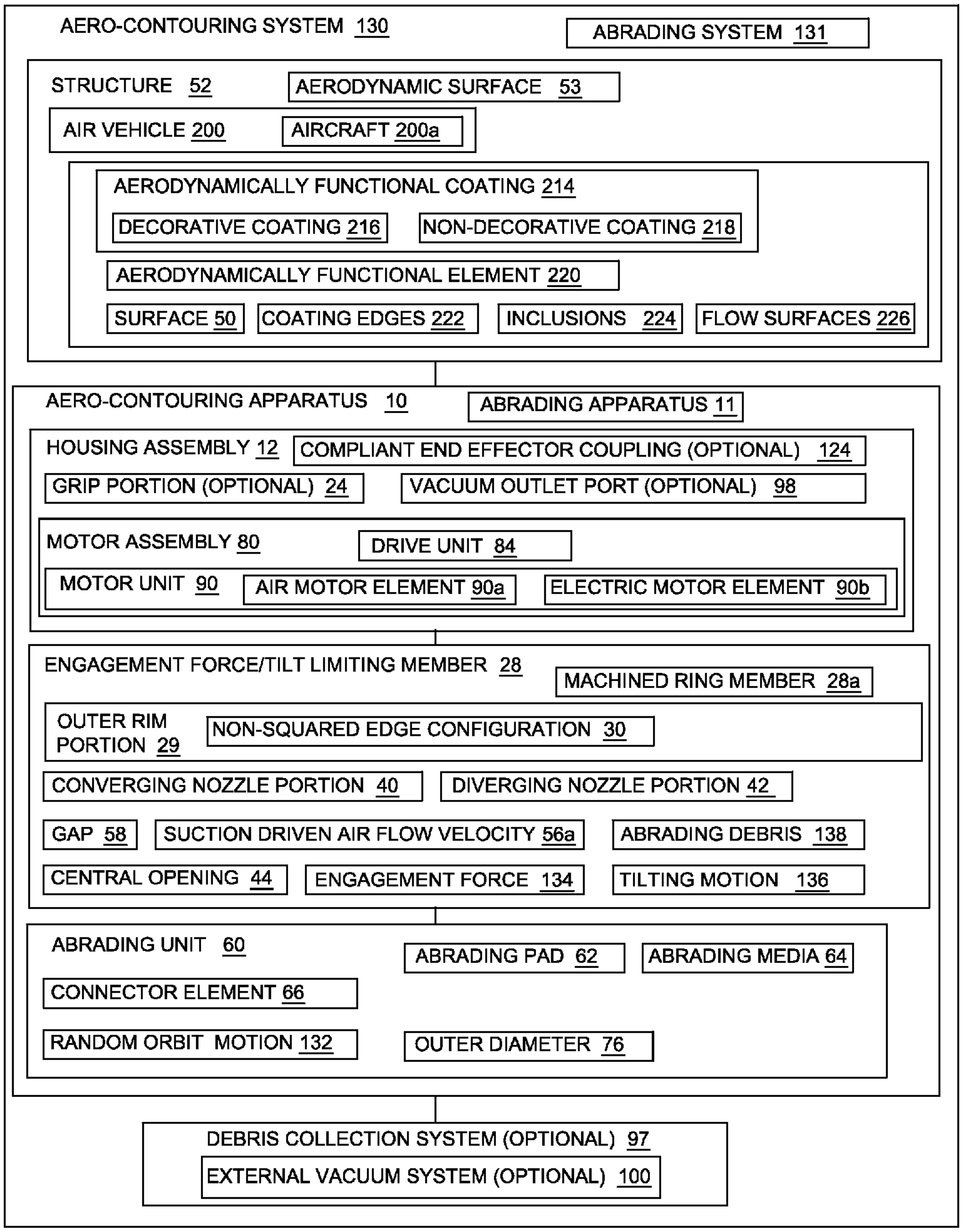

AERO-CONTOURING SYSTEM 130
ABRADING SYSTEM 131
STRUCTURE 52
AERODYNAMIC SURFACE 53
AIR VEHICLE 200
AIRCRAFT 200a
AERODYNAMICALLY FUNCTIONAL COATING 214
DECORATIVE COATING 216
NON-DECORATIVE COATING 218
AERODYNAMICALLY FUNCTIONAL ELEMENT 220
SURFACE 50
COATING EDGES 222
INCLUSIONS 224
FLOW SURFACES 226
AERO-CONTOURING APPARATUS 10
ABRADING APPARATUS 11
HOUSING ASSEMBLY 12
COMPLIANT END EFFECTOR COUPLING (OPTIONAL) 124
GRIP PORTION (OPTIONAL) 24
VACUUM OUTLET PORT (OPTIONAL) 98
MOTOR ASSEMBLY 80
DRIVE UNIT 84
MOTOR UNIT 90
AIR MOTOR ELEMENT 90a
ELECTRIC MOTOR ELEMENT 90b
ENGAGEMENT FORCE/TILT LIMITING MEMBER 28
MACHINED RING MEMBER 28a
OUTER RIM PORTION 29
NON-SQUARED EDGE CONFIGURATION 30
CONVERGING NOZZLE PORTION 40
DIVERGING NOZZLE PORTION 42
GAP 58
SUCTION DRIVEN AIR FLOW VELOCITY 56a
ABRADING DEBRIS 138
CENTRAL OPENING 44
ENGAGEMENT FORCE 134
TILTING MOTION 136
ABRADING UNIT 60
ABRADING PAD 62
ABRADING MEDIA 64
CONNECTOR ELEMENT 66
RANDOM ORBIT MOTION 132
OUTER DIAMETER 76
DEBRIS COLLECTION SYSTEM (OPTIONAL) 97
EXTERNAL VACUUM SYSTEM (OPTIONAL) 100

FIG. 6

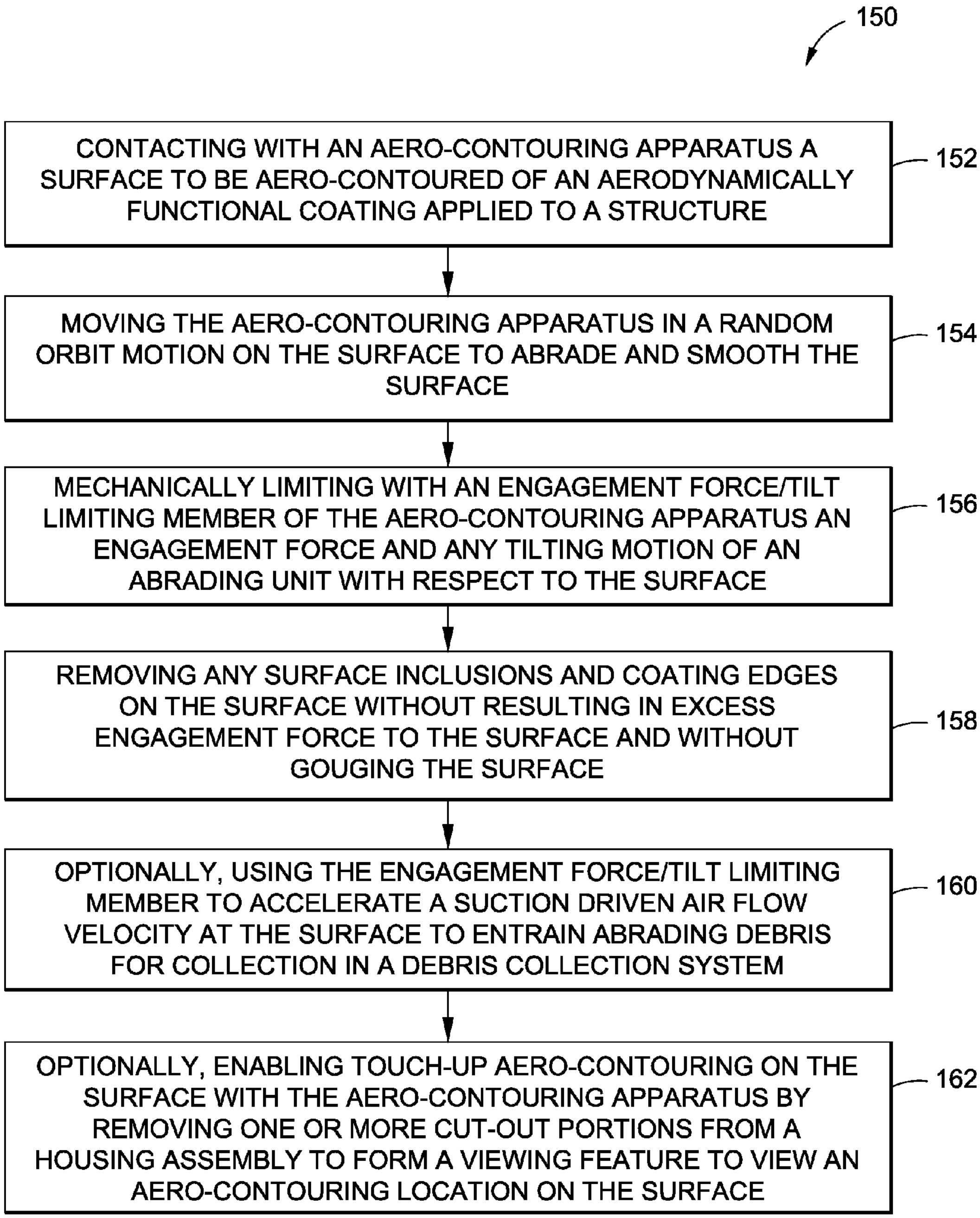

150
CONTACTING WITH AN AERO-CONTOURING APPARATUS A SURFACE TO BE AERO-CONTOURED OF AN AERODYNAMICALLY FUNCTIONAL COATING APPLIED TO A STRUCTURE
152
MOVING THE AERO-CONTOURING APPARATUS IN A RANDOM ORBIT MOTION ON THE SURFACE TO ABRADE AND SMOOTH THE SURFACE
154
MECHANICALLY LIMITING WITH AN ENGAGEMENT FORCE/TILT LIMITING MEMBER OF THE AERO-CONTOURING APPARATUS AN ENGAGEMENT FORCE AND ANY TILTING MOTION OF AN ABRADING UNIT WITH RESPECT TO THE SURFACE
156
REMOVING ANY SURFACE INCLUSIONS AND COATING EDGES ON THE SURFACE WITHOUT RESULTING IN EXCESS ENGAGEMENT FORCE TO THE SURFACE AND WITHOUT GOUGING THE SURFACE
158
OPTIONALLY, USING THE ENGAGEMENT FORCE/TILT LIMITING MEMBER TO ACCELERATE A SUCTION DRIVEN AIR FLOW VELOCITY AT THE SURFACE TO ENTRAIN ABRADING DEBRIS FOR COLLECTION IN A DEBRIS COLLECTION SYSTEM
160
OPTIONALLY, ENABLING TOUCH-UP AERO-CONTOURING ON THE SURFACE WITH THE AERO-CONTOURING APPARATUS BY REMOVING ONE OR MORE CUT-OUT PORTIONS FROM A HOUSING ASSEMBLY TO FORM A VIEWING FEATURE TO VIEW AN AERO-CONTOURING LOCATION ON THE SURFACE
162

FIG. 7

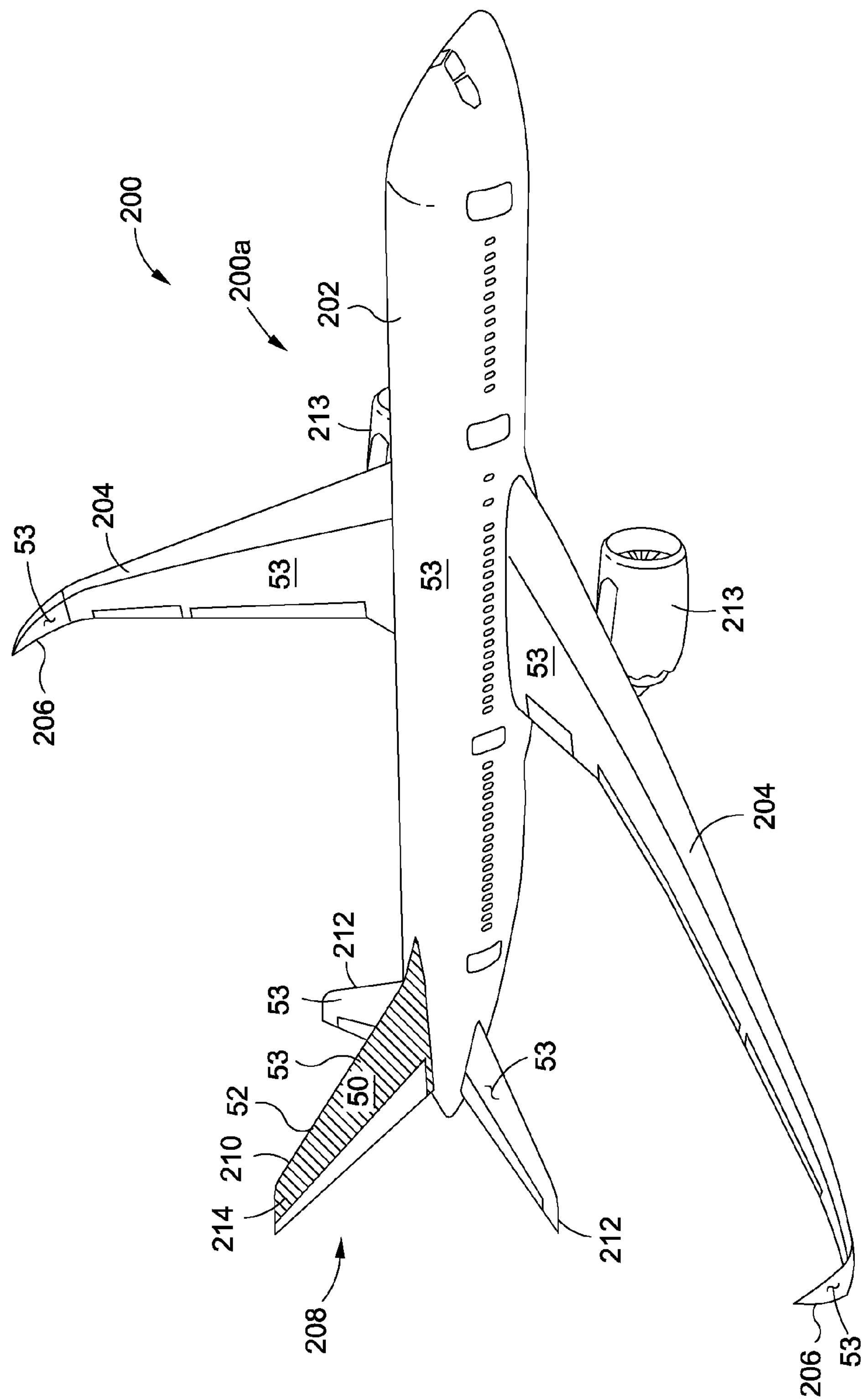
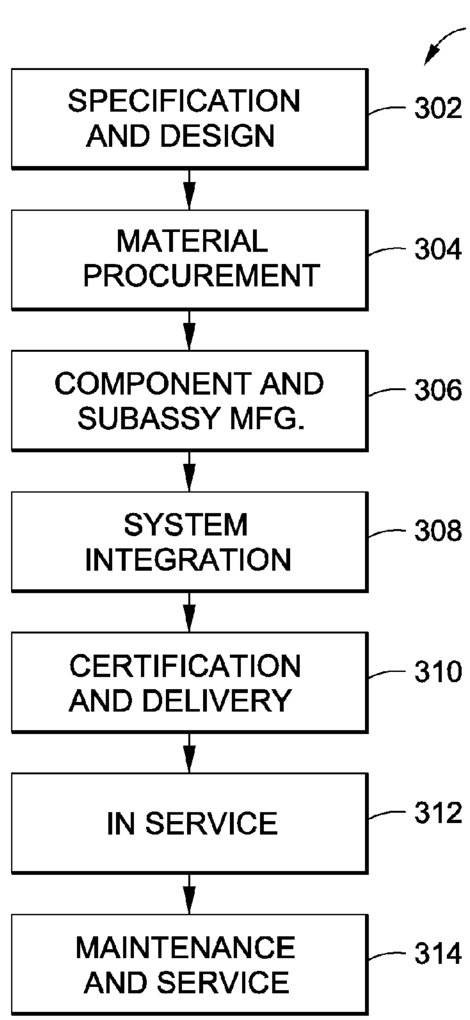


FIG. 8


300
SPECIFICATION AND DESIGN
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MATERIAL PROCUREMENT
304
COMPONENT AND SUBASSY MFG.
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SYSTEM INTEGRATION
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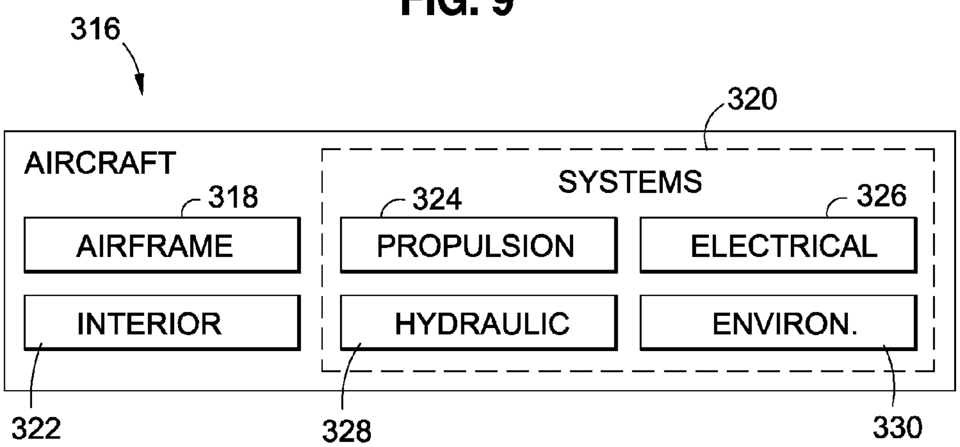
CERTIFICATION AND DELIVERY
310
IN SERVICE
312
MAINTENANCE AND SERVICE
314

FIG. 9


316
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SYSTEMS
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ELECTRICAL
INTERIOR
HYDRAULIC
ENVIRON.
322
328
330

FIG. 10

APPARATUS, SYSTEM AND METHOD FOR AERO-CONTOURING A SURFACE OF AN AERODYNAMICALLY FUNCTIONAL COATING

BACKGROUND

1) Field of the Disclosure

The disclosure relates generally to devices, methods and systems for aero-contouring surfaces of structures and collecting abrading debris, and more specifically, to devices, methods and systems for aero-contouring surfaces of aerodynamically functional coatings applied to structures of air vehicles, such as aircraft, and collecting abrading debris.

2) Description of Related Art

Air vehicles, such as commercial passenger and cargo aircraft, may have exterior surfaces that are coated or painted with colorful and decorative designs. For example, such exterior surfaces of an air vehicle may include exterior surfaces of the tail, wings, fuselage, nacelles, or other exterior surfaces of the air vehicle. Such colorful and decorative designs may include airline livery designs which are standard paint schemes on aircraft that prominently display an airline's logo, name, or other identifying feature to provide branding and differentiation of the airline. Since airline livery designs may provide not only a decorative function, but also a branding and differentiation function, it is important that livery designs be consistently applied and with acceptable appearance, gloss, and long-term durability.

In addition, maintaining desired air flow characteristics over coated or painted aircraft surfaces, such as airline livery designs, for example, coated or painted on the tail of an aircraft, may be challenging. In order to avoid impact on desired boundary layer characteristics during flight, there are allowable criteria for paint edges and waviness. There may also exist restrictions for three-dimensional surface discontinuities, such as those that may occur from inclusions caused by debris, dust, or dry coating overspray, which may be more stringent than for paint edges or for waviness.

Known devices, systems and methods exist for abrading or sanding coated or painted surfaces in order to smooth and polish the surfaces. However, smoothing and polishing of coating or paint edges of aerodynamically functional coatings, such as decorative livery designs, may require a manual process performed at a very high skill level and may require an extensive amount of time to achieve. A manual process performed by skilled operators may not scale well to the large areas and manufacturing rates required for commercial aircraft livery due to the time and skill required. Moreover, if lesser-skilled operators are used to perform the abrading or sanding, excessive pressure may inadvertently be applied to the surface during abrading or sanding, and/or gouging of the surface may occur if the abrading or sanding device is inadvertently tipped to the side. Further, although sanding with known sanding devices may be performed on coating or paint edges of decorative livery designs, this may not be a viable manufacturing method for exterior decorative livery design coatings or paints where appearance, gloss and long-term durability may be required.

Accordingly, there is a need in the art for improved devices, systems and methods for aero-contouring surfaces of aerodynamically functional coatings or paints of decorative designs, such as airline livery designs, applied to structures, such as structures of air vehicles, that provide advantages over known devices, systems and methods.

SUMMARY

This need for improved devices, systems and methods for aero-contouring surfaces of aerodynamically functional coatings or paints of decorative designs, such as airline livery designs, applied to structures, such as structures of air vehicles, is satisfied by this disclosure. As discussed in the below detailed description, embodiments of the improved devices, systems and methods for aero-contouring surfaces of aerodynamically functional coatings or paints of decorative designs, such as airline livery designs, applied to structures, such as structures of air vehicles, may provide significant advantages over known methods and systems.

In one embodiment of the disclosure, there is provided an aero-contouring apparatus. The aero-contouring apparatus comprises a housing assembly. The aero-contouring apparatus further comprises a motor assembly disposed within the housing assembly. The motor assembly comprises a motor unit and a drive unit.

The aero-contouring apparatus further comprises an engagement force/tilt limiting member coupled to the housing assembly. The engagement force/tilt limiting member has a central opening and has a bottom end configured to contact a surface to be aero-contoured of an aerodynamically functional coating applied to a structure. The aero-contouring apparatus further comprises an abrading unit coupled to the drive unit and inserted through the central opening in non-contact communication with the engagement force/tilt limiting member. The abrading unit is driven by the drive unit in a random orbit motion on the surface.

The housing assembly, the motor assembly, the engagement force/tilt limiting member, and the abrading unit, together comprise an aero-contouring apparatus for aero-contouring the surface to be aero-contoured, wherein the engagement force/tilt limiting member mechanically limits both an engagement force and any tilting motion of the abrading unit with respect to the surface. Optionally, the aero-contouring apparatus may comprise a vacuum outlet port configured for attachment to a debris collection device.

In another embodiment of the disclosure, there is provided an aero-contouring system. The aero-contouring system comprises a structure coated with an aerodynamically functional coating having a surface to be aero-contoured.

The aero-contouring system further comprises an aero-contouring apparatus for aero-contouring the surface. The aero-contouring apparatus comprises a housing assembly and a motor assembly disposed within the housing assembly. The motor assembly comprises a motor unit and a drive unit.

The aero-contouring system further comprises an engagement force/tilt limiting member coupled to the housing assembly. The engagement force/tilt limiting member has a central opening and has a bottom end configured to contact a surface to be aero-contoured of an aerodynamically functional coating applied to a structure. The aero-contouring system further comprises an abrading unit coupled to the drive unit and inserted through the central opening in non-contact communication with the engagement force/tilt limiting member. The abrading unit is driven by the drive unit in a random orbit motion on the surface. The engagement force/tilt limiting member mechanically limits both an engagement force and any tilting motion of the abrading unit with respect to the surface. Optionally, the aero-contouring system may comprise a debris collection system for attachment to the aero-contouring apparatus further comprising a vacuum outlet port.

In another embodiment of the disclosure, there is provided a method of aero-contouring a surface of an aerodynamically functional coating applied to a structure. The method comprises the step of contacting with an aero-contouring apparatus a surface to be aero-contoured of an aerodynamically functional coating applied to a structure.

The aero-contouring apparatus comprises a housing assembly and a motor assembly disposed within the housing assembly. The motor assembly comprises a motor unit and a drive unit. The aero-contouring apparatus further comprises an engagement force/tilt limiting member coupled to the housing assembly. The engagement force/tilt limiting member has a central opening. The aero-contouring apparatus further comprises an abrading unit coupled to the drive unit and inserted through the central opening in non-contact communication with the engagement force/tilt limiting member. Optionally, the aero-contouring apparatus may comprise a vacuum outlet port configured for attachment to a debris collection system.

The method further comprises the step of moving the aero-contouring apparatus in a random orbit motion on the surface to abrade and smooth the surface. The method further comprises the step of mechanically limiting with the engagement force/tilt limiting member an engagement force and any tilting motion of the abrading unit with respect to the surface. The method further comprises the step of removing any surface inclusions and coating edges on the surface without resulting in excessive engagement force to the surface and without gouging the surface.

The features, functions, and advantages that have been discussed can be achieved independently in various embodiments of the disclosure or may be combined in yet other embodiments further details of which can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure can be better understood with reference to the following detailed description taken in conjunction with the accompanying drawings which illustrate preferred and exemplary embodiments, but which are not necessarily drawn to scale, wherein:

FIG. **1**A is an illustration of a side perspective view of an embodiment of an aero-contouring apparatus of the disclosure for aero-contouring a surface;

FIG. **1**B is an illustration of a top perspective view of the aero-contouring apparatus of FIG. **1**A;

FIG. **1**C is an illustration of a side view of the aero-contouring apparatus of FIG. **1**A showing various internal components in phantom lines;

FIG. **2**A is an illustration of a bottom perspective view of another embodiment of an aero-contouring apparatus of the disclosure for aero-contouring a surface;

FIG. **2**B is an illustration of an exploded view of the aero-contouring apparatus of FIG. **2**A;

FIG. **2**C is an illustration of a side perspective view of yet another embodiment an aero-contouring apparatus of the disclosure for aero-contouring a surface;

FIG. **3**A is an illustration of a sectional view of an engagement force/tilt limiting member of the aero-contouring apparatus of the disclosure showing one embodiment of a non-squared edge configuration;

FIG. **3**B is an illustration of a sectional view of an engagement force/tilt limiting member of the aero-contouring apparatus of the disclosure showing another embodiment of a non-squared edge configuration;

FIG. **4**A is an illustration of a front perspective view of yet another embodiment of an aero-contouring apparatus of the disclosure for aero-contouring a surface;

FIG. **4**B is an illustration of a side view of the aero-contouring apparatus of FIG. **4**A;

FIG. **4**C is an illustration of a front view of the aero-contouring apparatus of FIG. **4**A;

FIG. **4**D is an illustration of a top plan view of the aero-contouring apparatus of FIG. **4**A;

FIG. **4**E is an illustration of a bottom plan view of the aero-contouring apparatus of FIG. **4**A;

FIG. **5**A is an illustration of a back perspective view of yet another embodiment of an aero-contouring apparatus of the disclosure for aero-contouring a surface;

FIG. **5**B is an illustration of a front perspective view of the aero-contouring apparatus of FIG. **5**A;

FIG. **5**C is an illustration of a front perspective view of the aero-contouring apparatus of FIG. **5**B with a compliant end effector coupling for robotic applications;

FIG. **6** is a block diagram of an embodiment of an aero-contouring system of the disclosure;

FIG. **7** is a flow diagram of an aero-contouring method of the disclosure;

FIG. **8** is a perspective view of an air vehicle that may incorporate one or more surfaces to be aero-contoured with one or more embodiments of the aero-contouring apparatus and aero-contouring system of the disclosure;

FIG. **9** is a flow diagram of an aircraft manufacturing and service method; and,

FIG. **10** is a block diagram of an aircraft.

DETAILED DESCRIPTION

Disclosed embodiments will now be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all of the disclosed embodiments are shown. Indeed, several different embodiments may be provided and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and will fully convey the scope of the disclosure to those skilled in the art.

Now referring to the Figures, FIGS. **1**A-**2**C and **4**A-**5**C show various embodiments of an aero-contouring apparatus **10** of the disclosure, for aero-contouring a surface **50** (see FIGS. **1**C and **4**A) to be aero-contoured of an aerodynamically functional coating **214** (see FIG. **8**) applied to a structure **52** (see FIGS. **1**C, **4**A, **8**). FIG. **6** is a block diagram of an embodiment of an aero-contouring system **130** incorporating an embodiment of the aero-contouring apparatus **10** of the disclosure. As used herein, "aero-contouring" means abrading, including fine abrading, smoothing and polishing, of a coated or painted surface of a structure, and in particular, a surface having an aerodynamically functional coating or paint applied to the structure, in order to remove or minimize the coating or paint edges (approximately right angle (90 degrees) steps), and to remove any surface inclusions or other particles or defects on the surface.

The aerodynamically functional coating **214** (see FIG. **8**) is preferably in the form of a paint or other suitable coating. Alternatively, the aero-contouring apparatus **10** may be used for aero-contouring a surface **50** (see FIGS. **1**C and **4**A) of an aerodynamically functional coating **220** comprising an aerodynamically functional film element **220** (see FIG. **6**), for example, an appliqué, applied to the structure **52** (see FIGS. **1**C, **4**A, **8**). The aerodynamically functional film element **220** (see FIG. **6**) may also be applied in addition to an aerodynamically functional paint on the structure **52** (see FIGS. **1**C, **4**A, **8**).

The aerodynamically functional coating **214** (see FIG. **8**) and the aerodynamically functional film element **220** (see FIG. **6**) may comprise a decorative coating **216** (see FIG. **6**) or a non-decorative coating **218** (see FIG. **6**). Preferably, the aerodynamically functional coating **214** (see FIG. **8**) and the aerodynamically functional film element **220** (see FIG. **6**) comprise a decorative coating **216** (see FIG. **6**), such as an airline livery design.

The surface **50** (see FIGS. **1**C, **4**A, **8**) to be aero-contoured is preferably in the form of a coated or painted surface **50***a* (see FIGS. **1**C, **3**) that is coated or painted with the aerodynamically functional coating **214** (see FIG. **8**) and/or the aerodynamically functional film element **220** (see FIG. **6**). The coated or painted surface **50***a* preferably comprises an exterior aerodynamic surface **53** (see FIG. **8**) of a structure **52** (see FIG. **8**) of an air vehicle **200** (see FIG. **8**), such as an aircraft **200***a* (see FIG. **8**). Structures **52** (see FIG. **8**) with exterior aerodynamic surfaces **53** (see FIG. **8**) may comprise one or more of a tail **208** (see FIG. **8**) of the air vehicle **200** (see FIG. **8**), including a vertical stabilizer tail portion **210** (see FIG. **8**) and horizontal stabilizer tail portions **212** (see FIG>**8**); wings **204** (see FIG. **8**) of the air vehicle **200** (see FIG. **8**), including winglets **206** (see FIG. **8**); a fuselage **202** (see FIG. **8**) of the air vehicle **200** (see FIG. **8**); nacelles **213** (see FIG. **8**) of the air vehicle **200** (see FIG. **8**); or other suitable structures with exterior aerodynamic surfaces.

Preferably, the aero-contouring apparatus **10** (see FIG. **6**) comprises an abrading apparatus **11** (see FIG. **6**) configured for random orbit motion **132** (see FIG. **6**) on the surface **50** (see FIG. **1**C) to be aero-contoured, for example, a random orbit sander. As used herein, "random orbit motion" means motion or movement in repetitive circular strokes, such as simultaneously spinning and moving in an ellipse, to produce a random orbit pattern. Because the aero-contouring apparatus **10** (see FIG. **6**) is preferably configured for random orbit motion **132**, during operation, no abrading debris **138** (see FIG. **6**) or particles travel the same path twice. This preferably results in an absence or reduction of swirl marks in the surface **50** (see FIGS. **1**C, **4**A, **8**) of the aerodynamically functional coating **214** (see FIG. **8**) after aero-contouring. Further, the aero-contouring apparatus **10** (see FIG. **6**) configured for random orbit motion **132** may be used to aero-contour a large surface area more rapidly as compared to non-random orbit motion devices.

The aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C) preferably comprises an abrading unit **60** (see FIGS. **1**A, **2**A-**2**B, **4**A), discussed in detail below, having an abrading media **64** (see FIG. **2**B), such as an abrasive film and loop element **64***a* (see FIG. **2**B). The abrading unit **60** (see FIG. **1**A), including the abrading media **64** (see FIG. **2**B), preferably both have an outer diameter **76** (see FIG. **2**A) with a length in a range of from about one (1) inch to about less than three (3) inches, and more preferably, both have an outer diameter **76** with a length in a range of from about one (1) inch to about one and a quarter (1.25) inch.

FIGS. **1**A-**1**C show one of the embodiments of the aero-contouring apparatus **10**, such as in the form of an aero-contouring apparatus **10***a*, for aero-contouring a surface **50** (see FIG. **1**C) to be aero-contoured of an aerodynamically functional coating **214** (see FIG. **8**) applied to the structure **52** (see FIG. **1**C). FIG. **1**A is an illustration of a side perspective view of the embodiment of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***a*, of the disclosure for aero-contouring the surface **50** (see FIG. **1**C). FIG. **1**B is an illustration of a top perspective view of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***a*, of FIG. **1**A. FIG. **1**C is an illustration of a side view of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***a*, of FIG. **1**A showing various internal components in phantom lines.

As shown in FIGS. **1**A-**1**C, the aero-contouring apparatus **10** comprises a housing assembly **12**. The housing assembly **12** may be in the form of a closed housing assembly **12***a* (see FIGS. **1**A, **2**A, **2**C, **5**A), or the housing assembly **12** may be in the form of an open housing assembly **12***b* (see FIG. **4**A). As shown in FIGS. **1**A-**1**C, the housing assembly **12** comprises a top end **14***a*, a bottom end **14***b*, and a body portion **16** there between. As further shown in FIGS. **1**A-**1**C, the body portion **16** may comprise a lower skirt portion **20** that flares outwardly at the bottom end **14***b* of the body portion **16** to facilitate collection of abrading debris **138** during aero-contouring of the surface **50** with the aero-contouring apparatus **10**. A lip portion **18** (see FIGS. **1**A-**1**C) may be formed in the skirt portion **20** (see FIGS. **1**A-**1**C) at the bottom end **14***b* (see FIGS. **1**A-**1**C).

The housing assembly **12** (see FIG. **1**A) may further comprise an open interior portion **22** (see FIG. **1**A) at the bottom end **14***b* (see FIG. **1**A). The open interior portion **22** (see FIG. **1**A) is preferably of a sufficient size and configuration to receive for installation within the housing assembly **12**, at least a motor assembly **80** (see FIG. **1**C), an engagement force/tilt limiting member **28** (see FIGS. **1**A-**1**C) and an abrading unit **60** (see FIGS. **1**A, **1**C).

As shown in FIGS. **1**A-**1**C, the housing assembly **12** may further comprise a grip portion **24** configured for manually holding the aero-contouring apparatus **10** during manual operation. The grip portion **24** (see FIGS. **1**A-**1**C) may be in the form of a side extending grip portion **24***a* (see FIGS. **1**A-**1**C, **2**C), a top grip portion **24***b* (see FIGS. **2**A-**2**B), a trigger handle grip portion **24***c* (see FIGS. **4**A-**5**B), or another suitable grip portion **24**. As shown in FIGS. **1**A-**1**C, **4**A-**4**B, **5**A-**5**B, the grip portion **24** has a first end **26***a* and a second end **26***b*. The second end **26***b* (see FIGS. **1**A-**1**C, **4**A-**4**B, **5**A-**5**B) is preferably integrated with the body **16** (see FIGS. **1**A-**1**C) or coupled to the body **16** (see FIGS. **4**A-**4**B, **5**A-**5**B). The grip portion **24** (see FIG. **1**A) and the body portion **16** (see FIG. **1**A) of the housing assembly **12** (see FIG. **1**A) are preferably made of a strong but flexible material, such as a strong, flexible plastic, nylon, vinyl or other suitable strong, flexible material.

As shown in FIGS. **1**A-**5**B, the aero-contouring apparatus **10** further comprises an engagement force/tilt limiting member **28** coupled to the housing assembly **12**. The engagement force/tilt limiting member **28** (see FIGS. **1**A, **2**A) is preferably in the form of a machined ring member **28***a* (see FIGS. **1**A, **2**A).

FIG. **3**A is an illustration of a sectional view of the engagement force/tilt limiting member **28** of the aero-contouring apparatus **10** (see FIGS. **1**A, **2**A) of the disclosure for aero-contouring a surface **50** of a structure **52**. FIG. **2**B also shows a side perspective view of the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*. As shown in FIGS. **2**B and **3**A, the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, has a first end **32***a*, a second end **32***b*, a body portion **36** there between, and a central through opening **44** (see FIGS. **1**A, **3**A) formed in the engagement force/tilt limiting member **28**. The bottom end **32***b* (see FIG. **3**A) of the engagement force/tilt limiting member **28** (see FIG. **3**A) is configured to contact the surface **50** (see FIG. **3**A) to be aero-contoured of the aerodynamically functional coating **214** (see FIG. **6**).

As further shown in FIGS. **2**B and **3**A, the body portion **36** of the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, comprises a coupling portion **34** having a plurality of coupling elements **34***a* formed in the coupling portion **34**. The coupling elements **34***a* may be in the form of snap fit coupling elements such as serrated snap fit coupling elements, or other suitable coupling elements. The coupling elements **34***a* (see FIG. **2**B) are configured to couple, and preferably snap fit, with a plurality of coupling element engagement portions **82** (see FIG. **2**B) formed in an interior wall **78** (see FIG. **2**B) of the body portion **16** of the housing assembly **12** (see FIG. **2**B). The engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, preferably securely snaps into the interior wall **78** (see FIG. **2**B) of the body portion **16** of the housing assembly **12** (see FIG. **2**B) but may also be removed if desired.

As further shown in FIGS. **2**B and **3**A, the body portion **36** of the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, comprises a base portion **38** having an outer rim portion **29** (see FIG. **3**A) with a non-squared edge configuration **30**. As shown in FIGS. **2**B and **3**A, the non-squared edge configuration **30** of the outer rim portion **29** (see FIG. **3**A) may comprise a beveled configuration **30***a*.

FIG. **3**B is an illustration of a sectional view of an engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, of the aero-contouring apparatus (see FIGS. **1**A, **2**A) of the disclosure showing another embodiment of a non-squared edge configuration **30**. As shown in FIG. **3**B, the non-squared edge configuration **30** of the outer rim portion **29** may comprise a continuous curve configuration **30***c*.

Alternatively, as shown in FIG. **4**A, the non-squared edge configuration **30** of the outer rim portion **29** may comprise a radiused configuration **30***b*. The outer rim portion **29** may also have another suitable non-squared edge configuration.

As further shown in FIG. **3**A, the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, has an inner diameter **46***a* equal to the diameter of the central through opening **44**, and has in outer diameter **46***b* equal to the outermost diameter of the outer rim portion **29**. FIG. **3**A further shows a centerline **54** running through the center of the central through opening **44**.

In one embodiment as shown in FIG. **2**A, the bottom end **32***b* of the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, is flat or substantially flat with the only opening being the central through opening **44**. In another embodiment as shown in FIGS. **2**C and **4**C, the bottom end **32***b* of the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, has a plurality of countersink openings **48**. As shown in FIGS. **2**C and **4**E, the countersink openings **48** may be spaced an equidistance apart from each other. As shown in FIG. **4**E, each of the countersink openings **48** is configured to receive a countersink element **108**.

As further shown in FIGS. **1**A and **3**A-**3**B, the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, comprises a converging nozzle portion **40** and a diverging nozzle portion **42**. As shown in FIGS. **3**A-**3**B, the converging nozzle portion **40** has a first tapered portion **41**, that preferably tapers inwardly and downwardly from the outermost portion of the outer rim portion **29** to the bottom end **32***b* of the engagement force/tilt limiting member **28**. As shown in FIGS. **3**A-**3**B, the diverging nozzle portion **42** has a second tapered portion **43**, that preferably tapers outwardly and upwardly from the bottom end **32***b* of the engagement force/tilt limiting member **28** toward the central through opening **44**. The geometry of the converging nozzle portion **40** and the diverging nozzle portion **42** effectively produces a convergent-divergent nozzle at the surface **50** (see FIGS. **3**A-**3**B) being aero-contoured or abraded. This convergent-divergent nozzle comprises the first tapered portion **41** (see FIGS. **3**A-**3**B) and the second tapered portion **43** (see FIGS. **3**A-**3**B) and accelerate the supplied suction driven air flow velocity **56***a* (see FIGS. **3**A-**3**B) at the surface **50** being aero-contoured or abraded. This, in turn, may improve collection of the abrading debris **138** (see FIG. **6**) by the developed geometry of the convergent-divergent nozzle feature.

When the aero-contouring apparatus **10** is configured for use with a debris collection system **97** (see FIGS. **2**B, **5**A), such as an external vacuum system **100** (see FIGS. **2**B, **5**A), the converging nozzle portion **40** (see FIGS. **3**A-**3**B) and the diverging nozzle portion **42** (see FIGS. **3**A-**3**B) together preferably accelerate a suction driven air flow velocity **56***a* (see FIG. **3**A) flowing within a gap **58** at the surface **50** (see FIGS. **3**A-**3**B) to entrain abrading debris **138** (see FIG. **6**) for collection in the debris collection system **97** (see FIGS. **2**B, **5**A), such as external vacuum system **100** (see FIGS. **2**B, **5**A).

As shown in FIGS. **3**A-**3**B, the gap **58** between the bottom end **32***b* of the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, and the surface **50**, such as the coated or painted surface **50***a*, is very narrow. The converging nozzle portion **40** (see FIGS. **3**A-**3**B) and the diverging nozzle portion **42** (see FIGS. **3**A-**3**B) preferably accelerate the suction driven air flow velocity **56***a* (see FIGS. **3**A-**3**B) within the gap **58** (see FIGS. **3**A-**3**B) and draw up a suction drawn air flow velocity **56***b* (see FIGS. **3**A-**3**B) through the central opening **44** (see FIGS. **3**A-**3**B). High velocity air flow within the gap **58** entrains, or draws in and transports, any abrading debris **138** (see FIG. **6**) or sanding debris for collection in the debris collection system **97** (see FIGS. **2**B, **5**A), such as the external vacuum system **100** (see FIGS. **2**B, **5**A) connected to the aero-contouring apparatus **10** (see FIGS. **2**B, **5**A). Thus, the aero-contouring apparatus **10** provides a confined flow path to collect abrading debris **138** (see FIG. **6**) for any aero-contouring apparatus **10** configured for use with a debris collection system **97** (see FIG. **2**B), such as an external vacuum system **100** (see FIG. **2**B).

The engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, is preferably made of a material that prevents or minimizes transfer of any contaminant material or residue material from the engagement force/tilt limiting member **28** (see FIGS. **3**A-**3**B) to the surface **50** (see FIGS. **3**A-**3**B) to be aero-contoured. The engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, is preferably constructed of a material, such as a strong and stiff acetal resin material, a strong and stiff nylon material, or another suitably strong and stiff plastic material, that prevents or minimizes transfer of any contaminant material or residue material from the engagement force/tilt limiting member **28** (see FIGS. **3**A-**3**B) to the surface **50** (see FIGS. **3**A-**3**B), such as the coated or painted surface **50***a* (see FIGS. **3**A-**3**B) to be aero-contoured. More preferably, the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, is made of DELRIN acetal resin. (DELRIN is a registered trademark of E.I. Du Pont de Nemours and Company of Wilmington, Del.)

In addition to the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, any other parts of the aero-contouring apparatus **10** that may directly contact the surface **50** (see FIGS. **3**A-**3**B), such as a coated or painted surface **50***a* (see FIGS. **3**A-**3**B), are also preferably made of a material that prevents or minimizes transfer of any contaminant material or residue material from the engagement force/tilt limiting member **28** (see FIGS. **3**A-**3**B) to the surface **50** (see FIGS. **3**A-**3**B) to be aero-contoured.

As shown in FIGS. **1**C and **2**C, the aero-contouring apparatus **10** further comprises a motor assembly **80** disposed within the housing assembly **12**. As further shown in FIGS.

1C and 2C, the motor assembly **80** comprises a motor unit **90** and a drive unit **84**. The motor unit **90** (see FIGS. **1**C, **2**C) may comprise an air motor element **90***a* (see FIG. **1**C, **2**C). Alternatively, the motor unit **90** may comprise an electric motor element **90***b* (see FIG. **6**) or another suitable motor unit.

As further shown in FIGS. **1**C and **2**C, the drive unit **84** has a first end **85***a* and a second end **85***b*. At the first end **85***a* (see FIG. **1**C) is an abrading unit engagement portion **86** (see FIGS. **1**C, **2**C). At the first end **85***b* (see FIG. **1**C) is a motor unit engagement portion **88** (see FIGS. **1**C, **2**C). The drive unit **84** may preferably comprise a rotary drive shaft adaptor unit or another suitable drive mechanism. The drive unit **84** (see FIG. **1**C) is preferably configured to drive or rotate an abrading unit **60** (see FIG. **1**C), such as in the form of a sanding unit **60***a* (see FIG. **1**C). The abrading unit engagement portion **86** (see FIG. **1**C) is preferably attached to the abrading unit **60** (see FIG. **1**C). The motor unit engagement portion **88** (see FIG. **1**C) is preferably attached to the motor unit **90** (see FIG. **1**C).

As shown in FIGS. **1**A-**2**C, **4**A-**5**C, the aero-contouring apparatus **10** further comprises the abrading unit **60** (see FIG. **1**C) coupled to the drive unit **84** (see FIG. **1**C) and inserted through the central opening **44** (see FIG. **2**C) in non-contact communication with the engagement force/tilt limiting member **28** (see FIG. **2**C), such as in the form of machined ring member **28***a* (see FIG. **2**C). The abrading unit **60** (see FIG. **2**C) is preferably attached to the abrading unit engagement portion **86** (see FIGS. **1**C, **2**C) driven by the drive unit **84** (see FIGS. **1**C, **2**C) in a random orbit motion **132** (see FIG. **6**) on the surface **50** (see FIG. **1**C).

The random orbit motion **132** may produce a random orbit abrading or sanding pattern by simultaneously spinning the abrading unit **60** and moving the abrading unit **60** in an ellipse. As shown in FIG. **1**A, the abrading unit **60**, such as in the form of sanding unit **60***a*, is preferably in an offset position **74** as compared to the engagement force/tilt limiting member **28** and as compared to the housing assembly **12** of the aero-contouring apparatus **10**.

As shown in FIGS. **2**B, **2**C, the abrading unit **60**, such as in the form of sanding unit **60***a* (see FIG. **2**C), comprises an abrading pad **62**, an abrading media **64** attached to one side of the abrading pad **62**, and a connector element **66** attached to the other side of the abrading pad **62**. As shown in FIG. **2**B, the abrading pad **62** has a first side **63***a* and a second side **63***b*. The abrading pad **62** (see FIG. **2**B) may preferably be in the form of a foam pad and hook element **62***a* (see FIG. **2**B). For example, the foam pad and hook element **62***a* may comprise a foam pad layer on the first side **63***a* and a hook layer on the second side **63***b*. The hook layer may be attached to the foam pad layer with an adhesive material.

As further shown in FIG. **2**B, the connector element **66** has a first side **67***a* and a second side **67***b*. The connector element **66** (see FIG. **2**B) may preferably be in the form of a twist lock connector **66***a* having a locking element **68**, such as in the form of a twist lock element **68***a*. The locking member **68** is preferably attached to the first side **67***a* of the connector element **66** and configured for connection to the drive unit **84** (see FIGS. **1**C, **2**C). As shown in FIG. **2**B, the first side **63***a* of the abrading pad **62** is preferably attached to the second side **67***b* of the connector element **66** with an adhesive material. As further shown in FIG. **2**B, the locking member **68** of the connector element **66** is preferably configured for insertion through an opening **70** and is configured for attachment to a connector element receiving element **72** positioned in the housing assembly **12**.

As shown in FIG. **2**B, the abrading media **64** has a first side **65***a* and a second side **65***b*. The first side **65***a* (see FIG. **2**B) of the abrading media **64** is preferably attached to the second side **63***b* (see FIG. **2**B) of the abrading pad **62** (see FIG. **2**B). The abrading media **64** (see FIG. **2**B) may preferably be in the form of an abrasive film and loop element **64***a* (see FIG. **2**B). For example, the abrasive film and loop element **64***a* (see FIG. **2**B) may comprise a loop layer on the first side **65***a* and an abrasive sanding film or sanding paper on the second side **65***b*. The abrasive sanding film or sanding paper of the abrading media **64** (see FIG. **2**B) preferably has a grit size sufficient for finish quality requirements. The abrading media **64** is designed to be a consumable item that is consumed or used up after one or more uses and may be replaced.

As shown in FIG. **2**A, the abrading unit **60**, including the abrading pad **62** (see FIG. **2**B), the abrading media **64** (see FIG. **2**B), the connector element **66** (see FIG. **2**A), preferably has an outer diameter **76** with a length in a range of from about one (1) inch to about less than three (3) inches, and more preferably, has an outer diameter **76** with a length in a range of from about one (1) inch to about one and a quarter (1.25) inch. The aero-contouring apparatus **10**, such as in the form of abrading apparatus **11** (see FIG. **6**), preferably has sufficient clearance to permit a random orbit motion **132** (see FIG. **6**) of the abrading unit **60** (see FIG. **2**B), such as in the form of a one and a quarter (1.25) inch diameter abrading unit **60**.

The aero-contouring apparatus **10**, such as in the form of abrading apparatus **11** (see FIG. **6**), preferably uses an abrading media **64** (see FIG. **2**B), such as in the form of abrasive film and loop element **64***a* (see FIG. **2**B), that is one and a quarter (1.25) inch diameter or slightly smaller in diameter to limit the aero-contoured or abraded area to that immediately near a coating edge **222** (see FIG. **6**) or surface inclusion **224** (see FIG. **6**) defect, making the aero-contouring process more controllable, and reducing the area with a visual difference between aero-contoured and non-aero-contoured areas after the aero-contouring. The aero-contouring apparatus **10** preferably maintains the second side **65***b* (see FIG. **1**A) of the abrading unit **60** (see FIGS. **1**A, **1**C) almost flush with the surface **50** (see FIG. **1**C), such as the coated or painted surface **50***a* (see FIG. **1**C), to facilitate control of the aero-contouring apparatus **10**, from tilting more than a few degrees and abrading or sanding through the aerodynamically functional coating **214** (see FIG. **6**).

As shown in FIGS. **1**A-**2**C and FIGS. **4**A-**5**C, the housing assembly **12**, the motor assembly **80**, the engagement force/tilt limiting member **28**, and the abrading unit **60**, together comprise an aero-contouring apparatus **10** for aero-contouring the surface **50** to be aero-contoured. The engagement force/tilt limiting member **28** (see FIG. **6**) mechanically limits both an engagement force **134** (see FIG. **6**) and any tilting motion **136** (see FIG. **6**) of the abrading unit **60** (see FIG. **6**) with respect to the surface **50** (see FIG. **6**). In particular, the engagement force/tilt limiting member **28** (see FIG. **6**) mechanically limits the engagement force of the abrading unit **60** (see FIG. **2**B), and in particular, the abrading media **64** (see FIG. **2**B), with a surface **50** to be aero-contoured.

In addition, the engagement force/tilt limiting member **28** (see FIG. **6**) mechanically limits any tilting of the abrading unit **60**, and in particular, the abrading pad **62** (see FIG. **2**B) and the abrading media **64** (see FIG. **2**B), with respect to the surface **50** (see FIGS. **1**C, **4**A) to prevent excessive sanding pressure on one side of the sanding unit **60**, such as abrading pad **62** or the abrading media **64**, which may result in gouging of the surface **50**. The aero-contouring apparatus **10** with the engagement force/tilt limiting member **28** (see FIG. **6**) is preferably designed to keep the abrading media **64** (see FIG. **2**B) in parallel or tangential contact with the surface **50** which may be flat or curved, that is to be aero-contoured or abraded.

In another embodiment, the aero-contouring apparatus **10**, such as in the form of abrading apparatus **11** (see FIG. **6**), comprises a debris collection system **97** (see FIG. **2**B), such as an external vacuum system **100** (see FIG. **2**B), for removing any abrading debris **138** (see FIG. **6**). As shown in FIGS. **2**A-**2**C, the aero-contouring apparatus **10** may be in the form of an aero-contouring apparatus **10***b*, having a vacuum outlet port **98** configured for attachment to a vacuum attachment element **101** (see FIG. **2**) connected to a debris collection system **97** (see FIG. **2**B), such as an external vacuum system **100** (see FIG. **2**B).

FIG. **2**A is an illustration of a bottom perspective view of the embodiment of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***b*, for aero-contouring the surface **50** (see FIGS. **1**C, **4**A, **8**). The aero-contouring apparatus **10** is used with a debris collection system **97** (see FIG. **2**B), such as an external vacuum system **100** (see FIG. **2**B). FIG. **2**B is an illustration of an exploded view of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***b*, of FIG. **2**A, showing the engagement force/tilt limiting member **28** and the abrading unit **60** separated from the housing assembly **12** of the aero-contouring apparatus **10** (see FIG. **2**B).

As shown in FIGS. **2**A-**2**B, the aero-contouring apparatus **10** comprises the housing assembly **12**, such as in the form of closed housing assembly **12***a*, having a top end **14***a*, a bottom end **14***b*, and a grip portion **24**, such as in the form of top grip portion **24***b*. As further shown in FIGS. **2**A-**2**B, the aero-contouring apparatus **10** comprises the engagement force/tilt limiting member **28** having a non-squared edge configuration **30**, such as comprising a radiused configuration **30***a*, and the abrading unit **60** inserted through the central through opening **44** (see FIG. **2**A).

As further shown in FIGS. **2**A-**2**B, the aero-contouring apparatus **10** comprises a limiting valve **92** attached to the motor unit **90**, such as an air motor element **90***a*. The limiting valve **92** preferably comprises an air motor exhaust restrictor, for example, an air motor variable exhaust restrictor that regulates the revolutions per minute (rpms) of the drive unit **84** which drives or rotates the attached abrading unit **60**.

As further shown in FIGS. **2**A-**2**B, the aero-contouring apparatus **10** comprises an exhaust assembly **94** having an exhaust tube portion **96**, a vacuum outlet port **98** with an attachment end **99**. As shown in FIG. **2**B, the attachment end **99** of the vacuum outlet port **98** is preferably configured for attachment with the vacuum attachment element **101** of the debris collection system **97**, such as the external vacuum system **100**.

FIG. **2**C is an illustration of another embodiment of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***c*, comprising another version of the engagement force/tilt limiting member **28** and another version of the housing assembly **12**. As shown in FIG. **2**C, the engagement force/tilt limiting member **28** has the plurality of countersink openings **48**, and the housing assembly **12** is preferably in the form of a closed housing assembly **12***a*. In addition, FIG. **2**C shows the aero-contouring apparatus **10***c* comprising a vacuum outlet port **98** configured for attachment to a vacuum attachment element **101** of a debris collection system **97**, such as an external vacuum system **100**.

In one embodiment as shown in FIGS. **4**A-**4**E, the aero-contouring apparatus **10** may be configured for performing touch-up aero-contouring, for example, of small surface areas. FIG. **4**A is an illustration of a front perspective view of another embodiment of an aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***d*, of the disclosure for aero-contouring a surface **50** of a structure **52**. The aero-contouring apparatus **10***d* of FIGS. **4**A-**4**E is preferably configured for touch-up applications of the surface **50** of the structure **52**. FIG. **4**B is an illustration of a side view of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***d*, of FIG. **4**A.

FIG. **4**C is an illustration of a front view of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***d*, of FIG. **4**A. FIG. **4**D is an illustration of a top plan view of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***d*, of FIG. **4**A. FIG. **4**E is an illustration of a bottom plan view of the aero-contouring apparatus o **10***d* f FIG. **4**A.

As shown in FIG. **4**A, in this embodiment, the housing assembly **12** comprises one or more cut-out portions **102** forming a viewing feature **103** enabling an operator to view an aero-contouring location **105** on the surface **50** of the structure **52** to be aero-contoured during touch-up aero-contouring with the aero-contouring apparatus **10**. For spot touch-up, the aero-contouring apparatus **103**, shown in FIGS. **4**A-**4**E provides a way of easily locate and view the aero-contouring location **105** to be aero-contoured or abraded while providing the prior mechanical limiting feature to prevent excessive sanding or gouging.

As further shown in FIG. **4**A, the housing assembly **12** is in the form of an open housing assembly **12***b* having leg portions **104** with openings **106** for receiving countersink elements **108** (see FIG. **4**E). In addition, as shown in FIG. **4**A, the housing assembly **12** may comprise a grip portion **24**, such as in the form of a trigger handle grip portion **24***c*, that extends from the top end **14***a* of the housing assembly **12**. The trigger handle grip portion **24***c* comprises a first end **26***a*, a second end **26***b*, and a trigger handle portion **114** (see FIG. **4**A). The trigger handle grip portion **24***c* houses the motor unit **90**, and the second end **26***b* of the trigger handle grip portion **24***c* is attached to the housing assembly **12**. As further shown in FIG. **4**A, the housing assembly **12** comprises a right angle gear box **110** and exhaust ports **112**.

As shown in FIG. **4**B, the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***d*, comprises the engagement force/tilt limiting member **28** having an outer rim portion **29** with a non-squared edge configuration **30**. The non-squared edge configuration **30** may comprise the radiused configuration **30***b* (see FIG. **4**B). Further, as shown in FIG. **4**B, the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***d*, comprises the motor assembly **80** comprising the drive unit **84**, the abrading unit engagement portion **86**, and the motor unit engagement portion **88**.

As shown in FIG. **4**E, the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***d*, comprises the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*. The engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*, preferably has on the bottom end **32***b*, the plurality of countersink openings **48** having countersink elements **108**, and an outer rim portion **29** with a non-squared edge configuration **30**, such as comprising a radiused configuration **30***b*.

FIG. **5**A is an illustration of a back perspective view of another embodiment of an aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***e*, where the aero-contouring apparatus **10** may be used with a clamp fixture **120**, for aero-contouring a surface **50**. As shown in FIG. **5**A, the aero-contouring apparatus **10***e* with the clamp fixture **120** is preferably configured for use with a debris collection system **97**, such as an external vacuum system **100** and configured for attachment to the vacuum attachment element **101** of the debris collection system **97**, such as the external vacuum system **100**.

FIG. **5**B is an illustration of a front perspective view of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***e*, of FIG. **5**A. As shown in FIGS. **5**A-**5**B, the clamp fixture **120** comprises a first portion **120***a* attached to a second portion **120***b* via attachment portions **122**. The clamp fixture **120** may be an extension of the top end **14***a* of the housing assembly **12**. As further shown in FIGS. **5**A-**5**B, the housing assembly **12** is a substantially closed housing assembly **12**, with openings **118** for receiving attachment elements (not shown) to enable attachment to the engagement force/tilt limiting member **28**, such as in the form of machined ring member **28***a*. As shown in FIGS. **5**A-**5**B, the engagement force/tilt limiting member **28** comprises a machined ring member **28***a* with a non-squared edge configuration **30**, such as comprising a radiused configuration **30***b*.

As further shown in FIGS. **5**A-**5**B, the housing assembly **12** comprises a grip portion **24**, such as in the form of trigger handle grip portion **24***c*, having a first end **26***a*, a second end **26***b*, and a trigger portion **114**. As further shown in FIGS. **5**A-**5**B, the housing assembly **12** comprises a vacuum outlet port **98** having an attachment end **99** configured for attachment to the vacuum attachment element **101** (see FIG. **5**A) of the debris collection system **97** (see FIG. **5**A), such as the external vacuum system **100** (see FIG. **5**A).

The aero-contouring apparatus **10** (see FIGS. **1**A, **2**A, **4**A, **5**A) may be used not only for manual applications but for automated applications, for example, robotic applications. If the aero-contouring apparatus **10** (see FIGS. **1**A, **2**A, **4**A, **5**A) is used for automated applications, for example, robotic applications, a compliant end effector coupling **124** (see FIG. **5**C) may be attached to the housing assembly **12** or integrally formed in the housing assembly **12**.

FIG. **5**C is an illustration of a front perspective view of the aero-contouring apparatus **10**, such as in the form of aero-contouring apparatus **10***e*, of FIG. **5**B, that may be used for automated applications such as robotic applications. The compliant end effector coupling **124** (see FIG. **5**C) is preferably configured for attachment to a robotic device **126** (see FIG. **5**C). The trigger portion **114** (see FIG. **5**B) may be removed from the aero-contouring apparatus **10***e* (see FIG. **5**C) and replaced with the compliant end effector coupling **124** (see FIG. **5**C), as the robotic device **126** is designed to hold or grip the grip portion **24** via the compliant end effector coupling **124** (see FIG. **5**C).

In another embodiment of the disclosure, there is provided an aero-contouring system **130**. FIG. **6** is a block diagram of an embodiment of an aero-contouring system **130** incorporating an embodiment of the aero-contouring apparatus **10** of the disclosure. Preferably, the aero-contouring system **130** (see FIG. **6**) comprises an abrading system **131** (see FIG. **6**), for example, a sanding and polishing system.

The aero-contouring system **130** comprises a structure **52** coated with an aerodynamically functional coating **214** having a surface **50** to be aero-contoured. The structure **52** comprises one or more of a tail **208** of an air vehicle **200**, including a vertical stabilizer tail portion **210** and horizontal stabilizer tail portions **212**; wings of an air vehicle **200**, including winglets **206**; fuselage **202** of an air vehicle **200**; and nacelles **213** of an air vehicle **200**. The structure **52** may be coated with an aerodynamically functional coating **214** comprising an aerodynamically functional film element **220**.

As shown in FIG. **6**, the aero-contouring system **130** further comprises an aero-contouring apparatus **10** for aero-contouring the surface **50**. The aero-contouring apparatus **10** comprises a housing assembly **12** and a motor assembly **80** disposed within the housing assembly **12**. The motor assembly **80** comprises a motor unit **90** and a drive unit **84**.

As shown in FIG. **6**, the aero-contouring apparatus **10** of the aero-contouring system **130** further comprises an engagement force/tilt limiting member **28** coupled to the housing assembly **12**. The engagement force/tilt limiting member **28** has a central opening **44** and has a bottom end **32***b* (see FIGS. **3**A-**3**B) configured to contact a surface **50** to be aero-contoured of an aerodynamically functional coating **214** applied to a structure **52**.

As shown in FIG. **6**, the engagement force/tilt limiting member **28** comprises a converging nozzle portion **40** and a diverging nozzle portion **42** that together accelerate a suction driven air flow velocity **56***a* at the surface **50** to be aero-contoured to entrain abrading debris **138** for collection in the debris collection system **97** (see also FIGS. **2**B, **2**C, **5**A), such as the external vacuum system **100** (see also FIGS. **2**B, **2**C, **5**A).

As shown in FIG. **6**, the aero-contouring apparatus **10** of the aero-contouring system **130** further comprises an abrading unit **60** coupled to the drive unit **84** and inserted through the central opening **44** in non-contact communication with the engagement force/tilt limiting member **28**. The abrading unit **60** (see FIG. **1**C) is driven by the drive unit **84** (see FIG. **1**C) in a random orbit motion **132** (see FIG. **6**) on the surface **50**. The engagement force/tilt limiting member **28** (see FIG. **6**) mechanically limits both an engagement force **134** (see FIG. **6**) and any tilting motion **136** (see FIG. **6**) of the abrading unit **60** (see FIG. **6**) with respect to the surface **50** (see FIG. **6**). Optionally, the aero-contouring system **130** may comprise a debris collection system **97**, such as an external vacuum system **100** (see FIG. **6**), for attachment to the aero-contouring apparatus **10**, where the aero-contouring apparatus **10** further comprises a vacuum outlet port **98** (see FIG. **6**).

As shown in FIG. **4**A, the aero-contouring apparatus **10** may be configured for performing touch-up aero-contouring of the surface **50**. As shown in FIG. **4**A, the housing assembly **12** comprises one or more cut-out portions **102** forming a viewing feature **103** enabling an operator to view an aero-contouring location **105** on the surface **50** during touch-up aero-contouring with the aero-contouring apparatus **10**.

In another embodiment of the disclosure, there is provided a method **150** of aero-contouring a surface **50** of an aerodynamically functional coating **214** applied to a structure **52**. FIG. **7** is a flow diagram of an aero-contouring method **150** of the disclosure. The method **150** of aero-contouring may be performed manually or may be automated. The method **150** comprises step **152** of contacting with an aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C) a surface **50** to be aero-contoured of an aerodynamically functional coating **214** (see FIG. **8**) applied to a structure **52**.

As shown in FIGS. **1**A-**2**C, **4**A-**5**C, the aero-contouring apparatus **10** comprises a housing assembly **12** and a motor assembly **90** disposed within the housing assembly **12**. As shown in FIGS. **1**A-**2**C, **4**A-**5**C, the motor assembly comprises a motor unit and a drive unit **84**. As shown in FIGS. **1**A-**2**C, **4**A-**5**C, the aero-contouring apparatus **10** further comprises an engagement force/tilt limiting member **28** coupled to the housing assembly **12**. The engagement force/tilt limiting member **28** has a central opening **44**. The aero-contouring apparatus **10** further comprises an abrading unit **60** coupled to the drive unit **84** and inserted through the central opening **44** in non-contact communication with the engagement force/tilt limiting member **28**.

As shown in FIG. **7**, the step **152** of contacting the surface **50** with the aero-contouring apparatus **10** preferably comprises contacting the surface **50** (see FIGS. **1**C, **4**A) with an abrading unit **60** (see FIGS. **1**C, **4**A) of the aero-contouring apparatus **10** (see FIGS. **1**C, **4**A), where the abrading unit **60** has an outer diameter **76** (see FIG. **2**A) with a length in a range of from about 1 inch to about 1.25 inch. The step **152** of contacting the surface **50** (see FIGS. **1**A, **4**A) further comprises forming the engagement force/tilt limiting member **28** (see FIGS. **1**A, **4**A) of a material that prevents or minimizes transfer of any contaminant material or residue material from the engagement force/tilt limiting member **128** to the surface **50** to be aero-contoured.

As shown in FIG. **7**, the method **150** further comprises step **154** of moving the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C) in a random orbit motion **132** (see FIG. **6**) on the surface **50** (see FIGS. **1**C, **4**A) to abrade and smooth the surface **50** (see FIGS. **1**C, **4**A). In particular, the abrading unit **60** (see FIG. **2**B) of the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C) may be moved in a random orbit motion **132** (see FIG. **6**) on the surface **50** (see FIGS. **1**C, **4**A) to abrade and smooth the surface **50** (see FIGS. **1**C, **4**A).

Abrading and smoothing the surface **50** (see FIGS. **1**C, **4**A) of the aerodynamically function coating **214**, and/or the aerodynamically functional element **220**, preferably comprise using the aero-contouring apparatus **10** (see FIGS. **1**A-**2**B, **4**A-**5**B), such as in the form of abrading apparatus **11** (see FIG. **11**), to abrade and smooth coating edges **222** (see FIG. **6**), such as paint edges and flow surfaces **226** (see FIG. **6**). In addition, abrading and smoothing the surface **50** (see FIGS. **1**C, **4**A) of the aerodynamically functional coating **214**, and/or the aerodynamically functional element **220**, preferably comprise using the aero-contouring apparatus **10** (see FIGS. **1**A-**2**B, **4**A-**5**C), such as in the form of abrading apparatus **11** (see FIG. **11**), to perform fine abrasion such as completely abrading the coating edges **222** (see FIG. **6**), such as paint edges, and flow surfaces **226** (see FIG. **6**) in order to blend the appearance of the surface **50** that has been aero-contoured and any non-aero-contoured surfaces.

As shown in FIG. **7**, the method **150** further comprises step **156** of mechanically limiting with the engagement force/tilt limiting member **28** (see FIGS. **2**A, **4**A) an engagement force **134** (see FIG. **6**) and any tilting motion **136** (see FIG. **6**) of the abrading unit **60** (see FIG. **6**) with respect to the surface **50** (see FIGS. **1**C, **3**, **4**A).

As shown in FIG. **7**, the method **150** further comprises step **158** of removing or minimizing any surface inclusions **224** (see FIG. **6**) and coating edges **222** (see FIG. **6**) on the surface **50** (see FIG. **6**) without causing excessive engagement force **134** (see FIG. **6**) to the surface **50** and without gouging of the surface **50** (see FIG. **6**). Surface inclusions **224** (see FIG. **6**) may comprise dust particles, debris particles, dry coating overspray, lint, or other particles or contaminants that may be present on the surface **50** (see FIGS. **1**C, **4**A) during or after aero-contouring of the surface **50** (see FIGS. **1**C, **4**A) with the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C). Three-dimensional surface discontinuities that may occur from such surface inclusions **224** (see FIG. **6**) may be even lower than coating edges **222**, such as in the form of right angle (**90** degrees) steps. Abrading debris **138** (see FIG. **6**) may be removed with a debris collection system **97** (see FIGS. **2**B-**2**C), such as an external vacuum system **100** (see FIGS. **2**B-**2**C), that may be attached to the aero-contouring apparatus **10** (see FIGS. **2**B-**2**C).

As shown in FIG. **7**, the method **150** may further comprise optional step **160** of using the engagement force/tilt limiting member **28** (see FIGS. **2**B, **3**) to accelerate the suction driven air flow velocity **56***a* (see FIG. **6**) at the surface **50** to entrain abrading debris **138** (see FIG. **6**) for collection in the debris collection system **97** (see FIGS. **2**B, **2**C, **5**A), such as the external vacuum system **100** (see FIGS. **2**B, **2**C, **5**A). The step **160** of using the engagement force/tilt limiting member **28** (see FIGS. **3**, **6**) to accelerate the suction driven air flow velocity **56***a* (see FIG. **6**) comprises using a converging nozzle portion **40** (see FIG. **6**) and a diverging nozzle portion **42** (see FIG. **6**) formed on the engagement force/tilt limiting member **28** (see FIG. **6**) to accelerate the suction driven air flow velocity **56***a* (see FIG. **6**).

As shown in FIG. **7**, the method **150** may further comprise optional step **162** of enabling touch-up aero-contouring on the surface **50** with the aero-contouring apparatus **10** (see FIG. **4**A) by removing one or more cut-out portions **102** (see FIG. **4**A) from the housing assembly **12** (see FIG. **4**A) to form a viewing feature **103** (see FIG. **4**A) to view an aero-contouring location **105** (see FIG. **4**A) on the surface **50** (see FIG. **4**A) of the structure **52** (see FIG. **4**A).

FIG. **8** is a perspective view of an air vehicle **200**, such as in the form of an aircraft **200***a*, that may incorporate one or more surfaces **50** of a structure **52**, such as exterior aerodynamic surfaces **53**, of a structure **52**, where the one or more surfaces **50** may be aero-contoured with one or more embodiments of the aero-contouring apparatus **10** of the disclosure. As shown in FIG. **8**, the air vehicle **200**, such as in the form of aircraft **200***a*, comprises a fuselage **202**, wings **204**, winglets **206**, a tail **208** comprising a vertical tail portion **210** and horizontal tail portions **212**, and nacelles **213**.

Although the aircraft **200***a* shown in FIG. **8** is generally representative of a commercial passenger aircraft having one or more structures **52** that may be coated with an aerodynamically functional coating **214**, such as in the form of a decorative coating **216** (see FIG. **6**) or a non-decorative coating **218** (see FIG. **6**), the teachings of the disclosed embodiments may be applied to other passenger aircraft. For example, the teachings of the disclosed embodiments may be applied to cargo aircraft, military aircraft, rotorcraft, and other types of aircraft or aerial vehicles, as well as aerospace vehicles, satellites, space launch vehicles, rockets, and other aerospace vehicles, that use decorative coatings **216** or non-decorative coatings **218**.

FIG. **9** is a flow diagram of an aircraft manufacturing and service method **300**. FIG. **10** is a block diagram of an embodiment of an aircraft **316**. Referring to FIGS. **9**-**10**, embodiments of the disclosure may be described in the context of the aircraft manufacturing and service method **300** as shown in FIG. **9**, and the aircraft **316** as shown in FIG. **10**.

During pre-production, exemplary aircraft manufacturing and service method **300** may include specification and design **302** of the aircraft **316** and material procurement **304**. During manufacturing, component and subassembly manufacturing **306** and system integration **308** of the aircraft **316** takes place. Thereafter, the aircraft **316** may go through certification and delivery **310** in order to be placed in service **312**. While in service **312** by a customer, the aircraft **316** may be scheduled for routine maintenance and service **314** (which may also include modification, reconfiguration, refurbishment, and other suitable services).

Each of the processes of the aircraft manufacturing and service method **300** may be performed or carried out by a system integrator, a third party, and/or an operator (e.g., a customer). For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors. A third party may include, without limitation, any number of vendors, subcontractors, and suppliers. An operator may include an airline, leasing company, military entity, service organization, and other suitable operators.

As shown in FIG. **10**, the aircraft **316** produced by the exemplary aircraft manufacturing and service method **300** may include an airframe **318** with a plurality of systems **320** and an interior **322**. Examples of the plurality of systems **322** may include one or more of a propulsion system **324**, an electrical system **326**, a hydraulic system **328**, and an environmental system **330**. Any number of other systems may be included. Although an aerospace example is shown, the principles of the disclosure may be applied to other industries, such as the automotive industry.

Methods and systems embodied herein may be employed during any one or more of the stages of the aircraft manufacturing and service method **300**. For example, components or subassemblies corresponding to component and subassembly manufacturing **306** may be fabricated or manufactured in a manner similar to components or subassemblies produced while the aircraft **316** is in service **312**. Also, one or more apparatus embodiments, method embodiments, or a combination thereof, may be utilized during component and subassembly manufacturing **306** and system integration **308**, for example, by substantially expediting assembly of or reducing the cost of the aircraft **316**. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof, may be utilized while the aircraft **316** is in service **312**, for example and without limitation, to maintenance and service **314**.

Disclosed embodiments of the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C), the aero-contouring system **130** (see FIG. **6**), and the method **150** (see FIG. **7**) for aero-contouring have numerous advantages and provide for the aero-contouring of aerodynamically functional coatings **214** (see FIG. **6**), such as decorative coatings **216** (see FIG. **6**), that meet the aerodynamic requirements to retain desired flow characteristics, while also preserving decorative appearance. Disclosed embodiments of the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C), the aero-contouring system **130** (see FIG. **6**), and the method **150** (see FIG. **7**) for aero-contouring may be used to aero-contour not only decorative coatings **216** (see FIG. **6**) on exterior aerodynamic surfaces **53** (see FIG. **8**) of aircraft **200***a* (see FIG. **8**), such as winglets **206** (see FIG. **8**) or the vertical stabilizer tail portion **210** (see FIG. **8**) where smooth coating or paint edges are desired to retain desired flow characteristics, but may also be used on non-decorative coatings **218** (see FIG. **6**), such as may be applied to wings **204** (see FIG. **8**) and horizontal stabilizer tail portions **212**(see FIG. **8**), where there may be a need for removal or repair of surface inclusions **224** (see FIG. **6**).

In addition, disclosed embodiments of the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C), the aero-contouring system **130** (see FIG. **6**), and the method **150** (see FIG. **7**) for aero-contouring use an abrading unit **60** (see FIG. **2**B) with an abrading media **64** (see FIG. **2**B) having an outer diameter **76** (see FIG. **2**A) having a length of preferably **1.25** inch or slightly smaller to limit the aero-contoured area to that immediately near the coating edge **222** (see FIG. **6**) or surface inclusion **224** (see FIG. **6**) defect, making the aero-contouring process more controllable, and reducing the area with a visual difference between aero-contoured and non-aero-contoured areas after the aero-contouring process.

Moreover, disclosed embodiments of the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C), the aero-contouring system **130** (see FIG. **6**), and the method **150** (see FIG. **7**) for aero-contouring mechanically limit the engagement force **134** (see FIG. **6**) of the abrading unit **60** (see FIGS. **1**C, **2**B) with the surface **50** (see FIG. **1**C) to be aero-contoured, mechanically limit tilting of the abrading unit **60** (see FIGS. **1**C, **2**B) with respect to the surface **50** (see FIG. **1**C) to prevent excessive aero-contouring pressure on one side of the abrading unit **60**, which may result in gouging the surface **50**, provide a confined flow path to collect abrading debris **138** (see FIG. **6**) for vacuum equipped aero-contouring apparatuses **10**, and provide for spot touch-ups of the surface **50** (see FIG. **4**A) by enabling a way of easily locating and viewing the location area **105** (see FIG. **4**A) to be aero-contoured while providing the prior mechanical limiting feature to prevent excessive aero-contouring or gouging.

Further, disclosed embodiments of the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C), the aero-contouring system **130** (see FIG. **6**), and the method **150** (see FIG. **7**) for aero-contouring provide an aero-contouring apparatus **10** that is preferably a random orbit motion type capable of random orbit motion **132** (see FIG. **6**) to reduce the instance of swirl marks in the surface **50** (see FIG. **6**) of the aerodynamically functional coating **214** (see FIG. **6**). In addition, all parts of the aero-contouring apparatus **10** that contact coated or painted surfaces **50***a* are preferably made of a material that does not leave residue that can affect subsequent coating operations.

Moreover, disclosed embodiments of the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C), the aero-contouring system **130** (see FIG. **6**), and the method **150** (see FIG. **7**) for aero-contouring may reduce the amount of time and skill necessary to manually aero-contour the surface **50** to be aero-contoured and allows for less skilled operators to produce desired results by preventing or minimizing excessive pressure to the surface **50** to be aero-contoured and by preventing or minimizing gouging of the surface **50** by enabling tipping the aero-contouring apparatus **10** during operation. In addition, the method **130** of aero-contouring may be performed manually or may be automated. Finally, disclosed embodiments of the aero-contouring apparatus **10** (see FIGS. **1**A-**2**C, **4**A-**5**C), the aero-contouring system **130** (see FIG. **6**), and the method **150** (see FIG. **7**) for aero-contouring may provide improved quality and aesthetics of surface finishes for marketing differentiation.

Many modifications and other embodiments of the disclosure will come to mind to one skilled in the art to which this disclosure pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. The embodiments described herein are meant to be illustrative and are not intended to be limiting or exhaustive. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

What is claimed is:

1. An aero-contouring apparatus comprising:

a housing assembly;

a motor assembly disposed within the housing assembly, the motor assembly comprising a motor unit and a drive unit;

an engagement force/tilt limiting member coupled to the housing assembly, the engagement force/tilt limiting member having a central through opening and having a substantially flat bottom end configured to maintain a gap between the bottom end and a surface to be aero-contoured of an aerodynamically functional coating applied to a structure, the engagement force/tilt limiting member comprising a machined ring member having a converging nozzle portion with a first tapered portion tapering downwardly from an outer rim portion of the machined ring member to the bottom end, and comprising a diverging nozzle portion with a second tapered portion tapering upwardly from the bottom end to the central through opening, the substantially flat bottom end having a radial thickness greater than a radial thickness of the first tapered portion and greater than a radial thickness of the second tapered portion, where the radial thickness is in relation to a centerline axis through the central through opening; and,

an abrading unit coupled to the drive unit and inserted through the central through opening in non-contact communication with the engagement force/tilt limiting member, the abrading unit driven by the drive unit in a random orbit motion on the surface,

the housing assembly, the motor assembly, the engagement force/tilt limiting member, and the abrading unit, together comprising an aero-contouring apparatus for aero-contouring the surface, wherein the engagement force/tilt limiting member mechanically limits both an engagement force and any tilting motion of the abrading unit with respect to the surface.

2. The apparatus of claim **1** wherein the housing assembly comprises a grip portion configured for manually holding the aero-contouring apparatus during manual operation.

3. The apparatus of claim **1** wherein the housing assembly comprises a vacuum outlet port configured for attachment to a debris collection system.

4. The apparatus of claim **3** wherein the converging nozzle portion and the diverging nozzle portion together accelerate a suction driven air flow velocity within the gap at the surface to be aero-contoured to entrain abrading debris for collection in the debris collection system.

5. The apparatus of claim **1** wherein the outer rim portion has a non-squared edge configuration comprising a beveled configuration, a radiused configuration, or a continuous curve configuration.

6. The apparatus of claim **1** wherein the engagement force/tilt limiting member is made of a material that prevents or minimizes transfer of any contaminant material or residue material from the engagement force/tilt limiting member to the surface to be aero-contoured.

7. The apparatus of claim **1** wherein the aero-contouring apparatus is configured for performing touch-up aero-contouring of the surface, and the housing assembly comprises one or more cut-out portions forming a viewing feature enabling an operator to view an aero-contouring location on the surface during touch-up aero-contouring with the aero-contouring apparatus.

8. The apparatus of claim **1** wherein the abrading unit comprises an abrading pad having a first side and a second side, a connector element attached to the first side and configured for connection to the drive unit, and an abrading media attached to the second side and configured for abrading the surface.

9. The apparatus of claim **1** wherein the abrading unit has an outer diameter with a length in a range of from about 1 inch to less than about 3 inches.

10. An aero-contouring system comprising:

a structure coated with an aerodynamically functional coating, the aerodynamically functional coating having a surface to be aero-contoured;

an aero-contouring apparatus for aero-contouring the surface, the aero-contouring apparatus comprising:

a housing assembly;

a motor assembly disposed within the housing assembly, the motor assembly comprising a motor unit and a drive unit;

an engagement force/tilt limiting member coupled to the housing assembly, the engagement force/tilt limiting member having a central through opening and having a substantially flat bottom end configured to maintain a gap between the bottom end and the surface, the engagement force/tilt limiting member comprising a machined ring member having a converging nozzle portion with a first tapered portion tapering downwardly from an outer rim portion of the machined ring member to the bottom end, and comprising a diverging nozzle portion with a second tapered portion tapering upwardly from the bottom end to the central through opening, the substantially flat bottom end having a radial thickness greater than a radial thickness of the first tapered portion and greater than a radial thickness of the second tapered portion, where the radial thickness is in relation to a centerline axis through the central through opening; and,

an abrading unit coupled to the drive unit and inserted through the central through opening in non-contact communication with the engagement force/tilt limiting member, the abrading unit driven by the drive unit in a random orbit motion on the surface,

wherein the engagement force/tilt limiting member mechanically limits both an engagement force and any tilting motion of the abrading unit with respect to the surface.

11. The system of claim **10** further comprising a debris collection system configured for attachment to a vacuum outlet port coupled to the housing assembly.

12. The system of claim **11** wherein the converging nozzle portion and the diverging nozzle portion together accelerate a suction driven air flow velocity within the gap at the surface to be aero-contoured to entrain abrading debris for collection in the debris collection system.

13. The system of claim **10** wherein the structure comprises one or more of a tail of an air vehicle, including a vertical stabilizer tail portion and horizontal stabilizer tail portions; wings of an air vehicle, including winglets; fuselage of an air vehicle; and nacelles of an air vehicle.

14. The system of claim **10** wherein the aerodynamically functional coating comprises an aerodynamically functional film element.

15. The system of claim **10** wherein the aero-contouring apparatus is configured for performing touch-up aero-contouring of the surface, and the housing assembly comprises one or more cut-out portions forming a viewing feature enabling an operator to view an aero-contouring location on the surface during touch-up aero-contouring with the aero-contouring apparatus.

16. A method for aero-contouring a surface of an aerodynamically functional coating applied to a structure, the method comprising the steps of:

contacting with an aero-contouring apparatus a surface to be aero-contoured of an aerodynamically functional coating applied to a structure, the aero-contouring apparatus comprising:

a housing assembly;

a motor assembly disposed within the housing assembly, the motor assembly comprising a motor unit and a drive unit;

an engagement force/tilt limiting member coupled to the housing assembly, the engagement force/tilt limiting member having a central through opening and a substantially flat bottom end configured to maintain a gap between the bottom end and the surface to be aero-contoured, the engagement force/tilt limiting member comprising a machined ring member having a converging nozzle portion with a first tapered portion tapering downwardly from an outer rim portion of the machined ring member to the bottom end, and comprising a diverging nozzle portion with a second tapered portion tapering upwardly from the bottom end to the central through opening, the substantially flat bottom end having a radial thickness greater than a radial thickness of the first tapered portion and greater than a radial thickness of the second tapered portion, where the radial thickness is in relation to a centerline axis through the central through opening; and,

an abrading unit coupled to the drive unit and inserted through the central through opening in non-contact communication with the engagement force/tilt limiting member;

moving the aero-contouring apparatus in a random orbit motion on the surface to abrade and smooth the surface;

mechanically limiting with the engagement force/tilt limiting member an engagement force and any tilting motion of the abrading unit with respect to the surface; and,

removing or minimizing any surface inclusions and coating edges on the surface without resulting in excessive engagement force to the surface and gouging of the surface.

17. The method of claim **16** further comprising the step of using the engagement force/tilt limiting member to accelerate a suction driven air flow velocity at the surface to entrain abrading debris for collection in a debris collection system.

18. The method of claim **17** wherein the step of using the engagement force/tilt limiting member to accelerate the suction driven air flow velocity comprises using the converging nozzle portion and the diverging nozzle portion formed on the engagement force/tilt limiting member to accelerate the suction driven air flow velocity within the gap.

19. The method of claim **16** further comprising the step of enabling touch-up aero-contouring on the surface with the aero-contouring apparatus by removing one or more cut-out portions from the housing assembly to form a viewing feature to view an aero-contouring location on the surface.

20. The method of claim **16** wherein the step of contacting the surface with the abrading unit comprises contacting the surface with an abrading unit having an outer diameter with a length in a range of from about 1 inch to less than about 3 inches.

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